

DOCUMENT RESUME

ED 370 798

SE 054 512

AUTHOR Zymelman, Manuel
TITLE Science, Education, and Development in Sub-Saharan Africa. Africa Technical Department Series. World Bank Technical Paper No. 124.
INSTITUTION World Bank, Washington, D. C.
REPORT NO ISBN-0-8213-1599-4
PUB DATE 90
NOTE 93p.; Statistical tables may not reproduce well due to small print type.
AVAILABLE FROM The International Bank for Reconstruction and Development, The World Bank, 1818 H Street, N.W., Washington, DC 20433.
PUB TYPE Reports - Research/Technical (143)
EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS College Science; Economic Development; Educational Change; Engineering Education; Foreign Countries; Higher Education; Science Curriculum; *Science Education; Scientific and Technical Information; Secondary Education; *Technology
IDENTIFIERS *Africa (Sub Sahara)

ABSTRACT

This paper deals with one aspect of technical change in Sub-Saharan Africa (SSA): the production of scientific and technical knowledge. Part I presents a quantitative view of the scientific output in SSA based on data from the Science Citation Index that provides information on scientific publications and citations by field and by country. Science universities are the focus of scientific research and training in SSA, Part II analyzes enrollments and outputs of universities in SSA in the area of science and engineering to ascertain their future role in fostering science and engineering. Any increase in the quantity and quality of university outputs in science and engineering will require the upgrade of the level of scientific and mathematics knowledge of the pool of entrants to higher education. Part III presents a picture of science education in secondary schools in a selected number of countries in SSA based on answers to a specially designed questionnaire. Part IV formulates a strategy for science and education in SSA and the possible role of the World Bank in this strategy. (Author/PR)

* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *

25

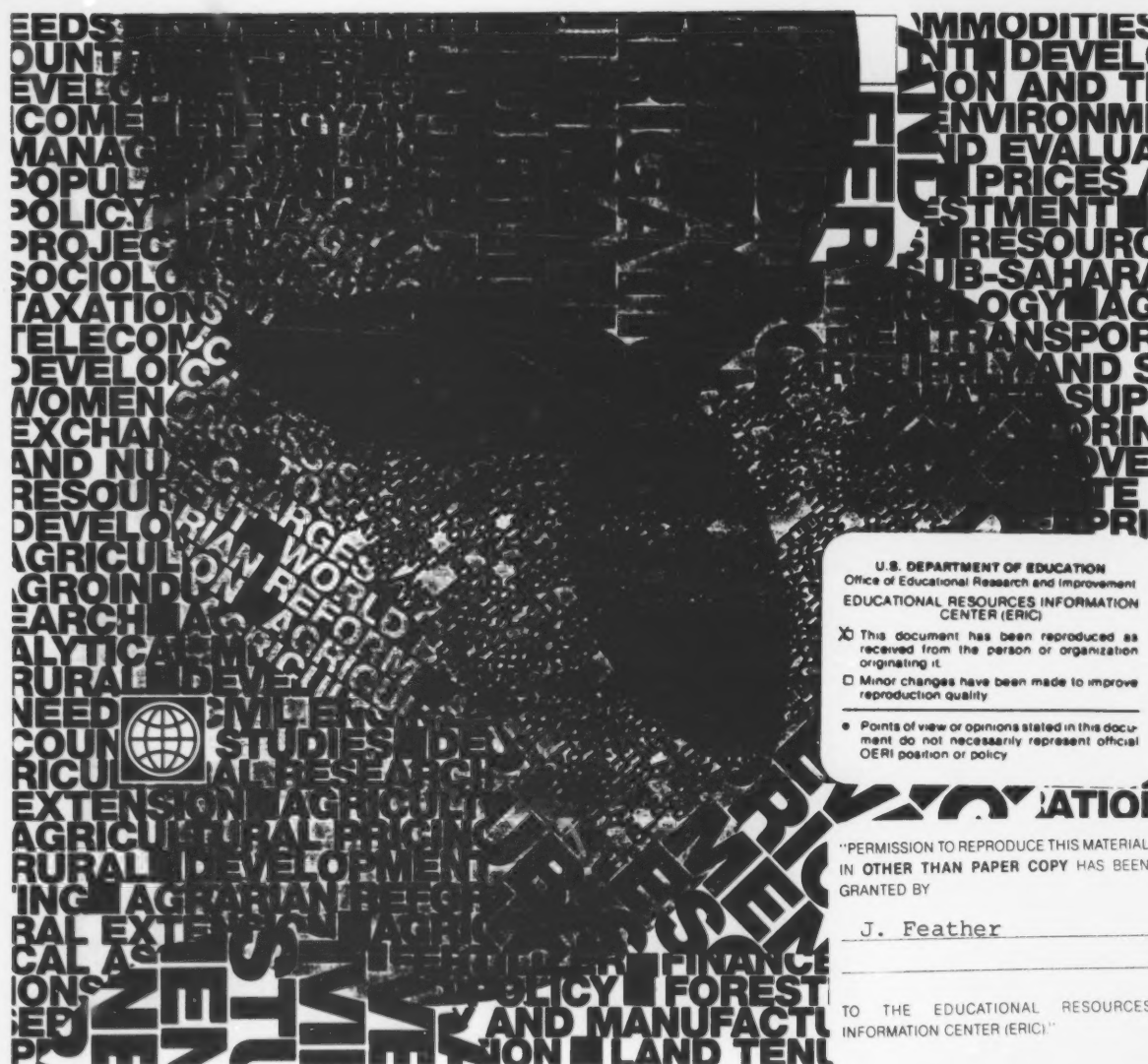
WORLD BANK TECHNICAL PAPER NUMBER 124
AFRICA TECHNICAL DEPARTMENT SERIES



ED 370 798

Science, Education, and Development in Sub-Saharan Africa

Manuel Zymelman



U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION
CENTER (ERIC)
☒ This document has been reproduced as
received from the person or organization
originating it.
☐ Minor changes have been made to improve
reproduction quality.
• Points of view or opinions stated in this docu-
ment do not necessarily represent official
OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL
IN OTHER THAN PAPER COPY HAS BEEN
GRANTED BY

J. Feather

TO THE EDUCATIONAL RESOURCES
INFORMATION CENTER (ERIC)"

SEO54512

RECENT WORLD BANK TECHNICAL PAPERS

- No. 63 Mould, *Financial Information for Management of a Development Finance Institution: Some Guidelines*
- No. 64 Hillel, *The Efficient Use of Water in Irrigation: Principles and Practices for Improving Irrigation in Arid and Semiarid Regions*
- No. 65 Hegstad and Newport, *Management Contracts: Main Features and Design Issues*
- No. 66F Godin, *Préparation des projets urbains d'aménagement*
- No. 67 Leach and Gowen, *Household Energy Handbook: An Interim Guide and Reference Manual* (also in French, 67F)
- No. 68 Armstrong-Wright and Thiriez, *Bus Services: Reducing Costs, Raising Standards*
- No. 69 Prevost, *Corrosion Protection of Pipelines Conveying Water and Wastewater: Guidelines*
- No. 70 Falloux and Mukendi, *Desertification Control and Renewable Resource Management in the Sahelian and Sudanian Zones of West Africa* (also in French, 70F)
- No. 71 Mahmood, *Reservoir Sedimentation: Impact, Extent, and Mitigation*
- No. 72 Jeffcoate and Saravanapavan, *The Reduction and Control of Unaccounted-for Water: Working Guidelines* (also in Spanish, 72S)
- No. 73 Palange and Zavala, *Water Pollution Control: Guidelines for Project Planning and Financing* (also in Spanish, 73S)
- No. 74 Hoban, *Evaluating Traffic Capacity and Improvements to Road Geometry*
- No. 75 Noetstaller, *Small-Scale Mining: A Review of the Issues*
- No. 76 Noetstaller, *Industrial Minerals: A Technical Review* (also in French, 76F)
- No. 77 Gunnerson, *Wastewater Management for Coastal Cities: The Ocean Disposal Option*
- No. 78 Heyneman and Fägerlind, *University Examinations and Standardized Testing: Principles, Experience, and Policy Options*
- No. 79 Murphy and Marchant, *Monitoring and Evaluation in Extension Agencies* (also in French, 79F)
- No. 80 Cernea, *Involuntary Resettlement in Development Projects: Policy Guidelines in World Bank-Financed Projects* (also in Spanish, 80S, and French, 80F)
- No. 81 Barrett, *Urban Transport in West Africa*
- No. 82 Vogel, *Cost Recovery in the Health Care Sector: Selected Country Studies in West Africa*
- No. 83 Ewing and Chalk, *The Forest Industries Sector: An Operational Strategy for Developing Countries*
- No. 84 Vergara and Brown, *The New Face of the World Petrochemical Sector: Implications for Developing Countries*
- No. 85 Ernst & Whinney, *Proposals for Monitoring the Performance of Electric Utilities*
- No. 86 Munasinghe, *Integrated National Energy Planning and Management: Methodology and Application to Sri Lanka*
- No. 87 Baxter, Slade, and Howell, *Aid and Agricultural Extension: Evidence from the World Bank and Other Donors*
- No. 88 Vuylsteke, *Techniques of Privatization of State-Owned Enterprises, vol. I: Methods and Implementation*
- No. 89 Nankani, *Techniques of Privatization of State-Owned Enterprises, vol. II: Selected Country Case Studies*
- No. 90 Candoy-Sekse, *Techniques of Privatization of State-Owned Enterprises, vol. III: Inventory of Country Experience and Reference Materials*
- No. 91 Reij, Mulder, and Begemann, *Water Harvesting for Plant Production: A Comprehensive Review of the Literature*
- No. 92 The Petroleum Finance Company, Ltd., *World Petroleum Markets: A Framework for Reliable Projection*

(List continues on the inside back cover)

Science, Education, and Development in Sub-Saharan Africa

Manuel Zymelman

The World Bank
Washington, D.C.

Copyright © 1990
The International Bank for Reconstruction
and Development / THE WORLD BANK
1818 H Street, N.W.
Washington, D.C. 20433, U.S.A.

All rights reserved
Manufactured in the United States of America
First printing June 1990
Second printing November 1993

Technical Papers are published to communicate the results of the Bank's work to the development community with the least possible delay. The typescript of this paper therefore has not been prepared in accordance with the procedures appropriate to formal printed texts, and the World Bank accepts no responsibility for errors.

The findings, interpretations, and conclusions expressed in this paper are entirely those of the author(s) and should not be attributed in any manner to the World Bank, to its affiliated organizations, or to members of its Board of Executive Directors or the countries they represent. The World Bank does not guarantee the accuracy of the data included in this publication and accepts no responsibility whatsoever for any consequence of their use. Any maps that accompany the text have been prepared solely for the convenience of readers; the designations and presentation of material in them do not imply the expression of any opinion whatsoever on the part of the World Bank, its affiliates, or its Board or member countries concerning the legal status of any country, territory, city, or area or of the authorities thereof or concerning the delimitation of its boundaries or its national affiliation.

The material in this publication is copyrighted. Requests for permission to reproduce portions of it should be sent to the Office of the Publisher at the address shown in the copyright notice above. The World Bank encourages dissemination of its work and will normally give permission promptly and, when the reproduction is for noncommercial purposes, without asking a fee. Permission to copy portions for classroom use is granted through the Copyright Clearance Center, 27 Congress Street, Salem, Massachusetts 01970, U.S.A.

The complete backlist of publications from the World Bank is shown in the annual *Index of Publications*, which contains an alphabetical title list (with full ordering information) and indexes of subjects, authors, and countries and regions. The latest edition is available free of charge from the Distribution Unit, Office of the Publisher, The World Bank, 1818 H Street, N.W., Washington, D.C. 20433, U.S.A., or from Publications, The World Bank, 66, avenue d'Iéna, 75116 Paris, France.

ISSN: 0253-7494

Manuel Zymelman is senior advisor, Economics of Education, in the Education and Training Division, Africa Technical Department, of the World Bank.

Library of Congress Cataloging-in-Publication Data

Zymelman, Manuel.

Science, education, and development in Sub-Saharan Africa / Manuel Zymelman.

p. cm. — (World Bank technical paper, ISSN 0253-7494 ; v. 124)

Includes bibliographical references.

ISBN 0-8213-1599-4

1. Science—Africa, Sub-Saharan. 2. Engineering—Africa, Sub-Saharan. 3. Science—Study and teaching—Africa, Sub-Saharan. 4. Engineering—Study and teaching—Africa, Sub-Saharan. 5. Science indicators—Africa, Sub-Saharan. I. Title. II. Series: World Bank technical paper ; no. 124.

Q127.A424Z96 1990

507.1'066—dc20

90-38700
CIP

ABSTRACT

Economic development of Sub-Saharan Africa (SSA) depends to a large extent on the ability of SSAn societies to introduce technical change, which in turn is the result of a confluence of many factor: scientific and technical knowledge, management, institutions, and proper economic and social environment. This paper deals only with one aspect of technical change in SSA: the production of scientific and technical knowledge. Part I presents a quantitative view of the scientific output in SSA based on data from the Science Citation Index that provides information on scientific publications and citations by field and by country. Since universities are the focus of scientific research and training in SSA, Part II analyzes enrollments and outputs of universities in SSA in the area of science and engineering to ascertain their future role in fostering science and engineering. Any increase in the quantity and quality of university outputs in science and engineering will require the upgrade of the level of scientific and mathematics knowledge of the pool of entrants to higher education. Part III presents a picture of science education in secondary schools in a selected number of countries in SSA based on answers to a specially designed questionnaire. Part IV formulates a strategy for science and education in SSA and the possible role the World Bank in this strategy.

ACKNOWLEDGEMENTS

I would like to thank Mr. Sandor Nagy for his help in programming the tables and figures contained in the paper, to Hodan Addou for organizing the data derived from questionnaires on secondary schools, and to Aurora Alba for typing the manuscript.

FOREWORD

Economic development in Sub-Saharan African countries depends foremost on the ability of their societies to establish technological progress as an ongoing process. This ability requires the capacity to choose, acquire, adapt, generate, and apply technologies. Scientific knowledge is a basic ingredient that helps develop this capacity.

The study "Science, Education, and Development in Sub-Saharan Africa (SSA)" presents for the first time quantitative measures of scientific output by country and field of study, and places Sub-Saharan African scientific efforts in an international context. In a search for solutions that would allow improvements in the present state of science and science education, the study also analyzes the output of scientific and technological manpower of universities and secondary schools. Following the diagnosis of the research and training systems the study suggests a strategy to increase the quantity and, especially, the quality of science education in SSA.

This study is intended for development agencies staff, government officials, and academicians concerned with science and science education, especially at the university level. By focusing on the inter-relationship of science, training, and economic resources, this study sets the framework for a healthy debate on policies required for addressing the problems confronting the development of science and science education in SSA.

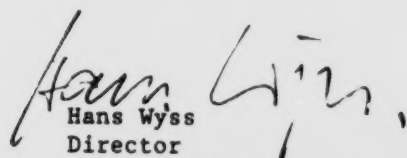

Hans Wyss
Director
Technical Department
Africa Region

TABLE OF CONTENTS

	Page Nos.
I. Scientific Output: A Quantitative View	1
Science Indicators in SSA Countries	6
Distribution of Publications by Country	7
Impact Measurement	7
Summary	8
Tables and Figures	10
II. Universities and Scientific Manpower	22
Tables and Figures	27
III. Science Education in Secondary Schools	49
Enrollment Rates	49
Summary	51
Tables	53
IV. A Strategy for Science Education in SSA	58
The Possible role of the Bank in the area of science teaching in SSA	63

I. SCIENTIFIC OUTPUT - A QUANTITATIVE VIEW -

Technical change has been credited in economic theory with being a major factor in economic growth. In growth models this factor was considered, in general, to be an autonomous process. But in real life technical change is the result of a confluence of many factors: scientific and technical knowledge, management, institutions, and proper economic and social environment.

Scientific and technical knowledge are usually mentioned together, however, for conceptual clarity it is necessary to distinguish between them. Scientific knowledge provides the understanding of nature and its behavior (the "know why"); technical knowledge provides the ability to manipulate the physical world (the "know how"). Science and technology exist in a symbiotic relationship: technology utilizes the advances of science to produce new and better products, while science progresses as a result of the validation or rejection of theories through experimentation done with instruments created with the available technology. This does not mean that either science or technology cannot progress without advances in the other. Historically, technology developed in many instances without the back-up of science, but in the long run scientific advances found their way into technology. The relationship between science and technology is lately becoming closer and, increasingly, advances in technology depend more and more on basic scientific knowledge.

Given that scientific knowledge is a necessary ingredient of economic growth the question for developing countries is: is it possible

to achieve sustained economic growth without developing the "scientific sector" since, after all, scientific knowledge is available worldwide. 1/

The case for developing an indigenous science establishment rests on many fronts:

1- There is undoubtedly a minimum threshold of scientific knowledge required for the proficient performance of technicians and professionals (doctors, engineers, agriculturists, etc.) in the economy. This threshold is rising continuously with the expansion of scientific knowledge and improvement of technology. To impart this knowledge it is necessary to have a functioning teaching scientific community that is able to relate to progress in science.

2- While technological knowledge can be acquired from abroad, to facilitate the transfer it is important to have individuals that can understand, assimilate, and, if necessary, transform and adapt this knowledge to local conditions. This, again, requires a minimum quantum of people with a solid scientific background.

3- A modern technological society requires more than the ability to perform skillfully; it requires a positive attitude to modernization. Science, by its questioning nature, influences the way man looks at the universe. This positive general attitude towards science can be fostered in the population at large only by a local scientific effort.

1/ Technical knowledge is more restricted because knowhow is more easily protected and to a large extent can only be acquired by "learning by doing".

4- To keep the morale of those engaged in science teaching, be it for developing technology, skills, or attitudes, it is crucial to develop and maintain scientific activities and link the local scientists to the international scientific community.

While it is not hard to justify the promotion of local science, it is difficult to quantify the "required" science, and determine the quality necessary for affecting economic development. Clearly, the assessment, if not the measurement, of science and its impact is a requisite for a rational allocation of resources for science research and teaching.

In principle there is a consensus as to the direct relationship between science and socio-economic growth, 2/ however, there is less agreement on the causality and, above all, the quantification of this relationship, both of which hinge on the ability to measure science. (Measures of socio-economic development are by no means easy to attain, but advances in methodology are way ahead of those dealing with measures of science).

Various methods have been suggested for measuring science. Economists tend to advocate the input - output approach, although in the end mostly inputs are measured because of the difficulty of measuring

2/ Derek J. De Solla Price "Measuring the size of science" in Little Science, Big Science and Beyond, Columbia University Press, N.Y. 1986.

outputs. For example, it is much easier to count the number of scientists engaged in research than to measure what these scientists produce.

The accepted indicators of scientific activity are:

for inputs:

- a) human resources in science - scientists, engineers, technicians, etc.
- b) finance and expenditures

for outputs

- a) scientific publications
- b) citation counts

There are other "linked" indicators or proxies such as percent of scientists in the population, patents, prizes, etc.

All these indicators appeal to scientists and economists alike for they provide a quantitative measure, but their reliability is no greater than the validity of the assumptions upon which they are based.

Strangely enough, in the case of SSA the input indicators, though easier to measure, are quite scarce and less reliable than the output indicators. For example, data of science inputs presented at CASTAFRICAII, in Arusha, Tanzania 1987, covers only a few countries and are mostly from the late 1970's. Moreover, science and technology manpower are badly defined, and expenditures on science cover at best only part of the scientific effort.

On the other hand output indicators, publications and citations, provide at least comparable international data.

However, output indicators also suffer from many drawbacks. Data Banks such as the Science Citation Index (SCI) ^{3/} reflects the scientific mainstream research and does not include all published research, especially research published in non or semi-scientific journals, or the efforts of those that produce something new that is not picked up in the literature. Moreover, most developed countries' journals are reluctant to increase the space provided to results from laboratories in third world countries where criteria for publications may be different, and there are too few local journals in developing countries where results could be published. Conditions in developing countries also militate against science publications: a) topics of research in developing countries are not as fashionable in developed countries; public health, tropical medicine, hybridization of corn cannot compete for attraction with molecular biology;

^{3/} The Data for output indicators is provided by the Institute of Scientific Information (ISI) which compiles bibliographical information on all scientific fields and publishes the Science Citation Index (SCI). This index covers eight major areas of science: Clinical Medicine, Biomedical research, Biology, Chemistry, Physics, Earth and Space, Engineering and technology, and Mathematics. (These areas are further disaggregated into 106 special fields). Since 1981, the index covers over 3,000 scientific journals selected from a universe of over 26000 journals to provide a uniform minimum level of acceptable quality. The extent of the activity of a given country in a scientific field is measured by dividing the country's number of publications in the field by the Region's or the World's publication in the same field. The Activity Index (AI), the ratio of the percentage of a country's research in a field by the percentage of the World's or Region's research in the same field, allows the comparison of the emphasis of different countries on fields of research.

The number of citations over a period of time to articles published in a given year referred to a given standard, for example average citations in a given field, allows international comparisons of the impact of the research on other scientists. But for all its statistical and computational advantages the data should be approached with caution.

b) ability to write in the "scientific" style and in the acceptable foreign language may be lacking; c) conditions conducive to publishing results, secretarial services, adequate rewards and professional recognition and advancement, may be lacking. For all of these reasons the number of publications and citations from developing countries may understate the actual scientific activities. Nevertheless, while these measures may understate some outputs, the relative situation of countries within a developing region, or compared to industrialized countries will not change very much.

Science Indicators in SSA Countries

Scientific research in SSA is very young ^{4/}. Nevertheless, since independence, parallel to the growth of the national universities, research developed gradually to the point where there is now a relatively stable, albeit small, scientific production in a selected number of fields. Table I-1 presents data on the number of scientific publications in SSA by field for the period 1981-1986.

The share of these publications in the world's total is approximately .4% which is much lower than the proportion of the SSA population in the world population (8.5%) (Table I-2). The distribution of the publications by field shows a heavy concentration in the life sciences: clinical medicine, biomedical research, and biology. Clinical medicine and biology alone comprise 72% of the total. This compares with 42% for Latin America and 44% for the world as a whole. In SSA the activity index (AI),

^{4/} For a description and concise history of scientific research in Africa see Jacques Gaillard et Roland Waast "La recherche scientifique en Afrique" Afrique Contemporaine 148, 3-30 (1988).

(a measure of the distribution of publications by field of a country or region compared with the same measure worldwide) for biology and clinical medicine is quite high compared with the world as a whole or Latin America, for example. (see Table 3 and Figure 1).

Distribution of Publications by Country

Ten countries supply almost 90% of the total scientific publications in SSA. Almost 70% is produced in three countries: Nigeria, Kenya and Sudan (see Table 4 and Figure 2). The number of publications by country is related to GDP ($r^2 = .95$); this measure has been found to be significant in international comparisons. ^{5/} The distribution of publications by field across countries is given in Table 5. This table shows, for example, that Nigeria accounts for more than half of all publications in most fields, while countries such as Ethiopia produce less than 1% in 4 out of 8 fields, and Zambia less than 2% in 5 of the 8 fields.

The distribution of publications by country and Activity Indexes (AI) (in this case a country's distribution of publications by field compared with the regional average) are given in Tables 6 and 7.

Impact Measurement

The number of citations of a given article has been considered an indicator of the impact of the article on the scientific community and, by implication, the quality of the work. Although social, institutional, and

^{5/} See D. De Solla Price, op. cit.

political factors influence publication and especially who quotes them, large discrepancies between the average number of citations conveys a sense of the difference in impact. The citations measures are: (a) the number of citations from the date of publication over a period of years; (b) the average citations per paper; (c) the Relative Citation Index (RCI) which is the ratio of the average citation per paper of a given country to the same ratio for the world or a particular region. Table 8 gives the number of papers by field and country and the world for 1981, and the number of citations for the publication that occurred during 1981-1986. Table 9 gives the average number of citations per article. Table 10 gives the RCI for the SSA countries, the world, and Latin America.

In general, the average citation per article in all fields is much lower in SSA than the world average. The RCI also shows that SSA countries rank lower than Latin America. It is interesting to note that the largest producers of research don't have the greatest RCI, and some lower producers rank higher in specific fields.

Summary

SSA contribution to scientific world publications is very small; less than half of one percent. Publications in the medical and biological fields have the lion's share while very few are in the physical and especially engineering sciences. This is a characteristic shared by most developing countries and reflects historical relationships between the industrialized world and developing countries, and a lack of coordination between objectives of research and economic goals. As in most regions of

the world the number of publications is strongly correlated with GDP, rather than GDP/capita. Thus three countries in SSA account for almost 70% of all scientific production. The number of citations per publication (a proxy for quality) is well below the world average and those of Latin America for example. But in SSA countries quantity of publications and citations per publication (quality) don't go hand in hand, many of the small producers of research merit higher number of citation per publication than the larger producers.

The facts presented above point to the necessity of promoting a strategy which aims at aligning SSA with the rest of the world by:

- (a) increasing the quantity of science research in SSA more in line with its share of population and GDP in the world;
- (b) redirecting the structure of the research more towards the physical sciences, mathematics, and engineering;
- (c) improving the quality of research.

This strategy requires increase of resources and, more importantly, qualified personnel which is the main limiting factor in the development of science. This leads us to look at the sources of scientific manpower supply.

TABLE I-1

PUBLICATION BY FIELD IN SSA (1981 - 1986)

	1981	1982	1983	1984	1985	1986	TOTAL
CLINICAL MEDICINE	704	654	696	666	744	713	4177
BIOMEDICAL RESEARCH	156	184	166	150	175	165	996
BIOLOGY	546	482	480	459	440	437	2844
CHEMISTRY	121	114	81	87	90	94	587
PHYSICS	43	45	37	32	31	32	220
EARTH AND SPACE	68	61	53	57	67	66	372
ENGINEERING & TECH	67	50	50	51	43	40	301
MATHEMATICS	19	28	24	29	35	12	147
TOTAL	1724	1618	1597	1531	1625	1559	9644

DISTRIBUTED BY FIELD

	1981	1982	1983	1984	1985	1986	Weighted Average
CLINICAL MEDICINE	0.41	0.40	0.44	0.43	0.46	0.46	0.43
BIOMEDICAL RESEARCH	0.09	0.11	0.10	0.10	0.11	0.11	0.10
BIOLOGY	0.32	0.30	0.30	0.30	0.28	0.28	0.29
CHEMISTRY	0.07	0.07	0.05	0.06	0.06	0.06	0.06
PHYSICS	0.02	0.03	0.02	0.02	0.02	0.02	0.02
EARTH AND SPACE	0.04	0.04	0.03	0.04	0.04	0.04	0.04
ENGINEERING & TECH	0.04	0.03	0.03	0.03	0.03	0.03	0.03
MATHEMATICS	0.01	0.02	0.02	0.02	0.02	0.02	0.02

Source: Data provided by Computer Horizons, Inc.

TABLE I-2

RATIO OF PUBLICATIONS SSA/WORLD

	1981	1982	1983	1984	1985	1986
CLINICAL MEDICINE	0.0080	0.0055	0.0058	0.0058	0.0059	0.0055
BIOMEDICAL RESEARCH	0.0028	0.0032	0.0029	0.0027	0.0027	0.0026
BIOLOGY	0.0139	0.0124	0.0127	0.0120	0.0126	0.0128
CHEMISTRY	0.0022	0.0021	0.0015	0.0016	0.0016	0.0017
PHYSICS	0.0009	0.0010	0.0008	0.0007	0.0008	0.0008
EARTH AND SPACE	0.0040	0.0037	0.0032	0.0003	0.0038	0.0036
ENGINEERING & TECH	0.0022	0.0017	0.0016	0.0017	0.0015	0.0015
MATHEMATICS	0.0018	0.0030	0.0025	0.0031	0.0037	0.0016

Source: Data provided by Computer Horizons, Inc.

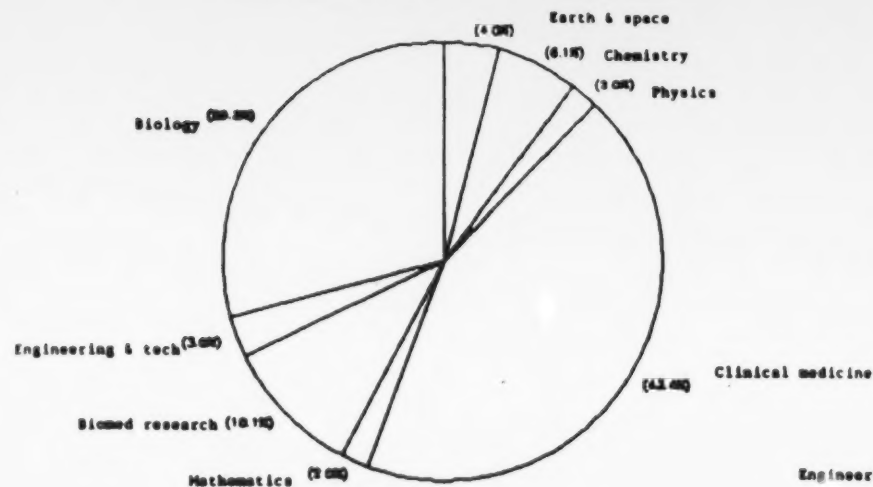
TABLE I-3

DISTRIBUTION OF PUBLICATIONS BY FIELD
AND ACTIVITY INDEXES FOR SSA & LA

	SSA	LA	WORLD	AI-SSA
CLINICAL MEDICINE	0.43	0.29	0.33	1.31
BIOMEDICAL RESEARCH	0.10	0.16	0.16	0.65
BIOLOGY	0.29	0.13	0.11	2.68
CHEMISTRY	0.06	0.13	0.16	0.38
PHYSICS	0.02	0.17	0.10	0.23
EARTH AND SPACE	0.04	0.05	0.05	0.77
ENGINEERING & TECH	0.03	0.04	0.07	0.44
MATHEMATICS	0.02	0.02	0.03	0.51

Source: Data for SSA and World provided by Computer Horizons, Inc.
Data for Latin America pertain 1980 - 1984 only are taken from
Economic and Social Progress in Latin America, Ch. IX, Inter-American
Development Bank, Washington, DC, 1988.

DISTRIBUTION OF PUBLICATIONS BY FIELD IN SSA



DISTRIBUTION OF PUBLICATIONS BY FIELD IN LA

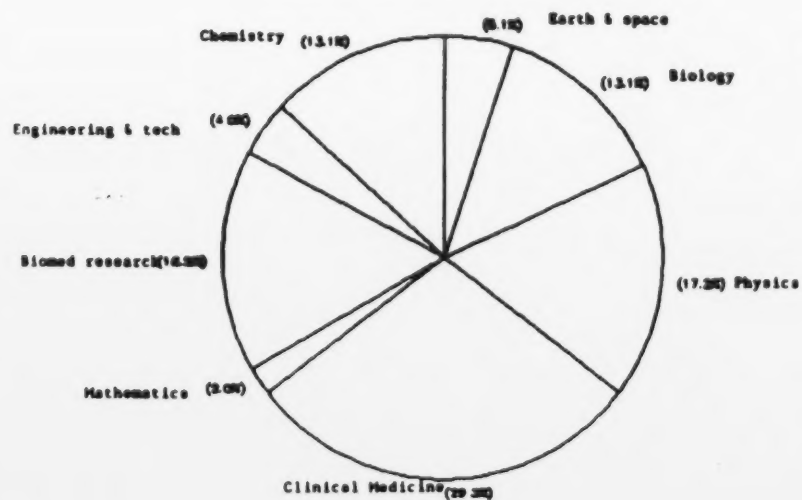


FIGURE 1-1

DISTRIBUTION OF PUBLICATIONS BY FIELD IN THE WORLD

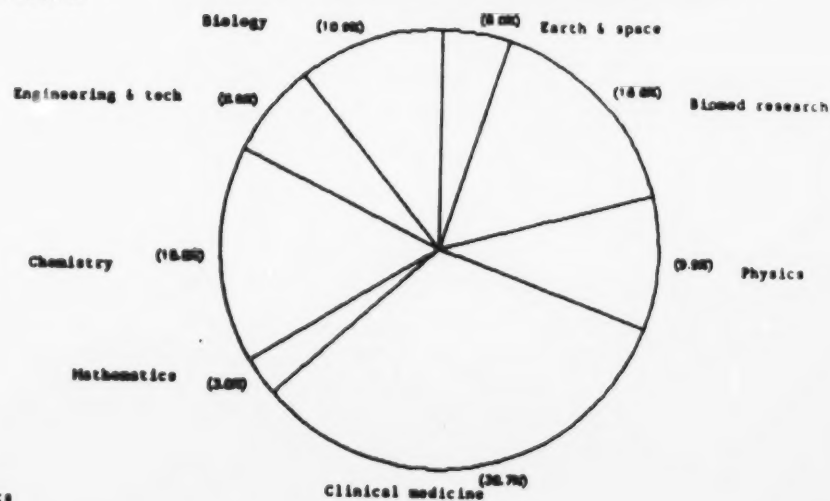


TABLE I-4

THE TEN LARGEST PRODUCERS OF RESEARCH

	1981	1982	1983	1984	1985	1986	1981-1986	SHARE
NIGERIA	781	793	749	712	758	736	4529	0.47
KENYA	266	252	243	234	250	209	1454	0.15
SUDAN	94	88	91	107	94	84	558	0.06
ZIMBABWE	86	78	47	56	72	70	407	0.04
TANZANIA	72	68	63	54	67	69	393	0.04
SENEGAMBI	64	43	66	59	69	57	358	0.04
ETHIOPIA	29	34	48	37	33	40	219	0.02
IVORY COAST	78	54	44	46	30	40	290	0.03
ZAIRE	16	14	19	22	22	26	119	0.01
ZAMBIA	27	25	31	40	27	22	172	0.02
OTHER	212	172	188	165	202	207	1146	0.12
TOTAL	1728	1619	1587	1532	1624	1580	9645	1.00

Source: Data provided by Computer Horizons, Inc.

THE TEN LARGEST PRODUCERS OF RESEARCH

FIGURE I-2

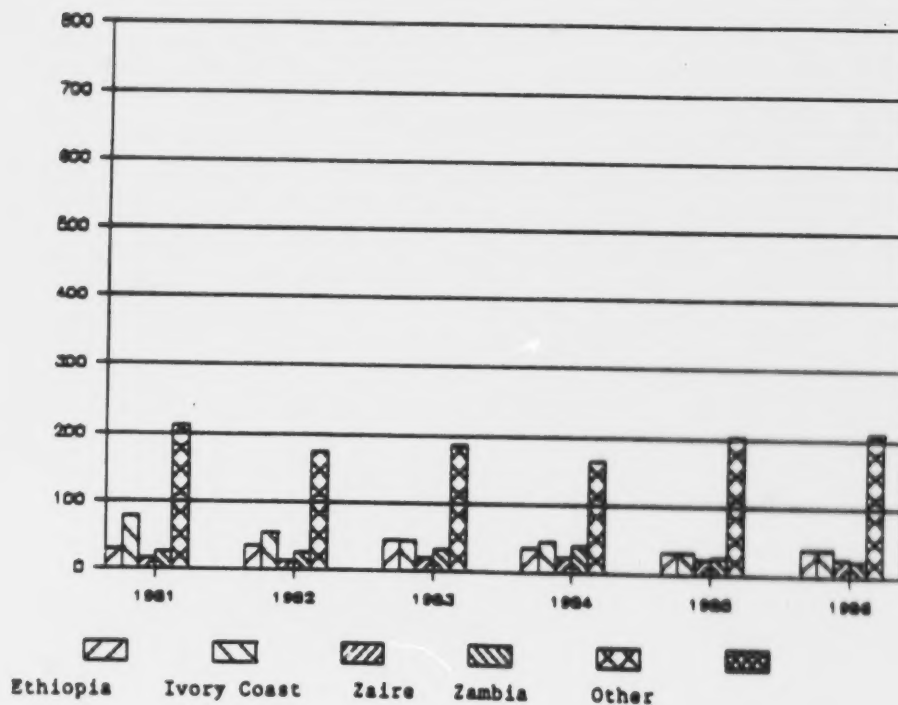
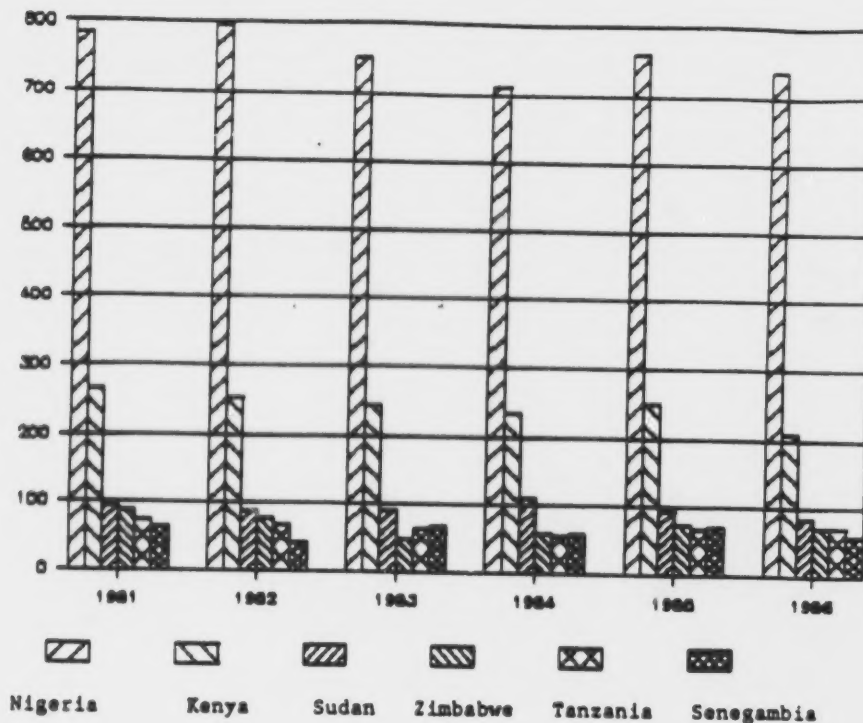


TABLE I-5

COUNTRY DISTRIBUTION OF PUBLISHED RESEARCH BY FIELD (in percent)

	NIGERIA	KENYA	SUDAN	ZIMBAB.	TANZA.	SENEGAM	ETHIO	IV CST	ZAIRE	ZAMBIA	OTHER	TOTAL
CLINICAL MEDICINE	41.2	21.4	6.1	3.1	4.4	3.2	3.1	2.1	1.8	2.5	11.1	100.0
BIOMEDICAL RESEARCH	54.4	16.8	4.3	3.0	1.2	8.1	0.6	2.3	0.4	0.4	8.9	100.0
BIOLOGY	45.5	11.0	6.7	7.0	5.4	2.6	1.7	4.2	0.4	1.2	14.4	100.0
CHEMISTRY	59.1	2.9	4.4	1.2	1.9	3.4	4.1	5.5	2.4	0.7	14.5	100.0
PHYSICS	58.2	5.0	1.8	2.3	3.2	6.4	0.0	5.9	2.7	2.7	11.8	100.0
EARTH AND SPACE	54.8	7.8	4.3	3.2	3.5	5.6	0.8	3.0	1.1	3.5	12.4	100.0
ENGINEERING & TECH	72.4	6.3	4.7	4.7	4.0	1.3	0.3	1.3	1.0	1.3	2.7	100.0
MATHEMATICS	51.7	11.6	8.2	8.2	2.0	2.7	5.4	0.7	0.0	1.4	8.2	100.0

Source: Data provided by Computer Horizons, Inc.

TABLE I-6

DISTRIBUTION BY FIELD BY COUNTRY

	NIGERIA	KENYA	SUDAN	ZIMBAB.	TANZA.	SENEGAM	ETHIO	IV CST	ZAIRE	ZAMBIA	AV. SSA
CLINICAL MEDICINE	0.38	0.61	0.46	0.32	0.47	0.38	0.59	0.30	0.64	0.61	0.43
BIOMEDICAL RESEARCH	0.12	0.11	0.08	0.07	0.03	0.23	0.03	0.08	0.03	0.02	0.10
BIOLOGY	0.29	0.21	0.34	0.49	0.39	0.21	0.22	0.41	0.10	0.20	0.29
CHEMISTRY	0.08	0.01	0.06	0.02	0.03	0.06	0.11	0.11	0.12	0.02	0.06
PHYSICS	0.03	0.01	0.01	0.01	0.02	0.04	0.00	0.04	0.05	0.03	0.02
EARTH AND SPACE	0.05	0.02	0.03	0.03	0.03	0.06	0.01	0.04	0.03	0.06	0.04
ENGINEERING & TECH	0.06	0.01	0.03	0.03	0.03	0.01	0.00	0.01	0.03	0.02	0.03
MATHEMATICS	0.02	0.01	0.02	0.03	0.01	0.01	0.04	0.00	0.00	0.01	0.02

- 17 -

Source: Data provided by Computer Horizons, Inc.

TABLE I-7

ACTIVITY INDEX (1981 - 1986)

	NIGERIA	KENYA	SUDAN	ZIMBAB.	TANZA.	SENEGAM	ETHIO	IV CST	ZAIRE	ZAMBIA
CLINICAL MEDICINE	0.88	1.42	1.06	0.74	1.08	0.88	1.37	0.69	1.49	1.42
BIOMEDICAL RESEARCH	1.20	1.11	0.77	0.74	0.30	2.31	0.27	0.79	0.34	0.23
BIOLOGY	0.98	0.74	1.17	1.68	1.34	0.72	0.78	1.43	0.35	0.68
CHEMISTRY	1.28	0.19	0.77	0.29	0.46	0.95	1.80	1.84	1.98	0.39
PHYSICS	1.41	0.38	0.38	0.61	0.89	2.00	0.00	2.24	2.52	1.73
EARTH AND SPACE	1.13	0.50	0.71	0.74	0.82	1.50	0.34	0.95	0.84	1.88
ENGINEERING & TECH	1.60	0.43	0.83	1.14	1.01	0.38	0.15	0.46	0.84	0.77
MATHEMATICS	0.84	0.58	1.07	1.47	0.38	0.57	1.80	0.17	0.00	0.58

Source: Data provided by Computer Horizons, Inc.

TABLE I-8

1981 JOURNAL SET

NUMBER OF PAPERS IN 1981

FIELD SUBFIELD NAME	NIGERIA	KENYA	SUDAN	ZIMBAB.	TANZA.	GAMBIA	SENEGAL	ETHIOP.	IV CST	ZAIRE	ZAMBIA	WORLD
CLINICAL MEDICINE	287	155	41	18	25	9	18	23	15	10	12	115398
BIOMEDICAL RESEARCH	77	33	8	9	4	2	13	1	5	1	0	59195
BIOLOGY	222	61	25	48	23	0	12	5	19	1	3	34719
CHEMISTRY	75	3	4	2	2	0	4	1	10	2	1	52929
PHYSICS	27	2	0	0	3	0	0	0	1	4	0	48878
EARTH AND SPACE	43	6	4	4	3	0	1	0	2	1	3	17584
ENGINEERING & TECH	35	2	7	0	5	0	1	0	1	0	3	25089
MATHEMATICS	10	2	3	1	1	0	1	2	0	0	1	9407
ALL FIELDS COMBINED	778	284	92	80	68	11	50	32	53	19	23	383175

NUMBER OF CITATIONS (1981-1988)

CLINICAL MEDICINE	458	384	65	51	49	53	155	88	42	35	13	837889
BIOMEDICAL RESEARCH	110	279	17	28	4	18	78	0	15	1	1	887857
BIOLOGY	361	123	30	55	50	0	32	1	27	1	1	134655
CHEMISTRY	188	13	11	6	4	0	13	0	29	4	0	283277
PHYSICS	22	4	0	0	1	0	0	0	2	3	0	321276
EARTH AND SPACE	68	4	8	35	4	0	1	0	2	4	8	115500
ENGINEERING & TECH	47	1	7	0	9	0	1	0	2	0	1	57916
MATHEMATICS	2	1	1	2	0	0	0	4	0	0	0	18552
ALL FIELDS COMBINED	1254	809	139	177	121	71	280	91	119	48	24	2456722

TABLE I-9

CITATIONS PER PAPER

FIELD	NIGERIA	KENYA	SUDAN	ZIMBAB.	TANZAN.	GAMBIA	SENEGAL	ETHIOP.	IV CST	ZAIRE	ZAMBIA	WORLD
CLINICAL MEDICINE	1.59	2.48	1.59	3.12	1.98	5.81	8.81	3.78	2.82	3.64	1.11	7.28
BIOMEDICAL RESEARCH	1.43	8.57	2.04	3.11	0.89	9.58	5.91	0.00	3.00	1.00	2.00	11.62
BIOLOGY	1.63	2.01	1.18	1.14	2.15	0.00	2.63	0.19	1.41	1.00	0.33	3.88
CHEMISTRY	2.50	4.71	2.75	3.00	2.00	0.00	3.28	0.00	3.00	2.80	0.00	5.35
PHYSICS	0.81	2.33	0.00	0.00	0.33	0.00	0.00	0.00	2.15	0.88	0.00	6.57
EARTH AND SPACE	1.58	0.78	1.88	10.00	1.17	0.00	0.48	0.00	0.71	4.00	2.87	6.57
ENGINEERING & TECH	1.38	0.43	1.08	0.00	1.75	0.00	1.00	0.00	2.00	0.00	0.30	2.31
MATHEMATICS	0.21	0.50	0.40	3.00	0.00	0.00	0.00	2.67	0.00	0.00	0.00	1.97
ALL FIELD COMBINED	1.62	3.08	1.52	2.22	1.80	6.44	5.70	2.89	2.25	2.73	1.02	6.78

- 20 -

TABLE I-10

CITATION INDEX

NAME	NIGERIA	KENYA	SUDAN	ZIMBAB.	TANZAN.	GAMBIA	SENEGAL	ETHIOP.	IV CST	ZAIRE	ZAMBIA	WORLD	L.A.1/
CLINICAL MEDICINE	0.22	0.34	0.22	0.43	0.27	0.80	1.21	0.52	0.39	0.50	0.15	1.00	0.58
BIOMEDICAL RESEARCH	0.12	0.74	0.18	0.27	0.08	0.82	0.51	0.00	0.28	0.09	0.17	1.00	0.51
BIOLOGY	0.42	0.52	0.30	0.29	0.55	0.00	0.88	0.05	0.36	0.28	0.09	1.00	0.90
CHEMISTRY	0.47	0.88	0.51	0.58	0.37	0.00	0.81	0.00	0.58	0.49	0.00	1.00	0.48
PHYSICS	0.12	0.35	0.00	0.00	0.05	0.00	0.00	0.00	0.33	0.13	0.00	1.00	0.89
EARCH & SPACE	0.24	0.12	0.29	1.52	0.18	0.00	0.07	0.00	0.11	0.81	0.41	1.00	1.12
ENGINEERING & TECH	0.59	0.19	0.47	0.00	0.78	0.00	0.43	0.00	0.87	0.00	0.13	1.00	0.37
MATHEMATICS	0.11	0.25	0.20	1.52	0.00	0.00	0.00	1.35	0.00	0.00	0.00	1.00	0.81
ALL FIELDS COMBINED	0.30	0.43	0.27	0.39	0.38	0.80	0.80	0.45	0.39	0.40	0.18	1.00	0.80

1/ Data for L.A. is for articles published in 1980 and Citations for the period 1980-1984.

II. UNIVERSITIES AND SCIENTIFIC MANPOWER

All over the world universities are the locus of scientific research and training. Their role is largest in lesser developed nations. Whereas in industrialized countries much research and training is done in private industry, non profit organizations, and other government agencies, in poor developing countries universities produce the lion's share of research and training. Therefore, to talk of science and technology in SSA means, to a large extent, to focus on the university, its ability to provide training, and its capacity to produce graduates in science and engineering.

There is a dearth of data on SSA's universities. Fewer than 15 countries provide data on enrollments by field of study, and fewer than half a dozen publish data on graduates by level and field of study on a time series basis. Nevertheless, it is possible to compare various SSA countries as a group with groups from Latin America (LA) and OECD countries.

If we compare total enrollments in higher education per 100,000 population in the three groups (SSA, LA, OECD), the averages for SSA is 89, for LA 1468, and for OECD 2392; a ratio of 1:16:27. The ratio for enrollments in the natural sciences is more favorable for the SSA countries (1:6:16) but the ratio for engineering is worse (1:25:40). (See table 1 and figures 1.1 to 1.5).

The picture is bleaker when one analyzes graduates. The number of graduates per 100,000 population for SSA, LA, and OECD is 13.8, 121.4, and 411 respectively - a ratio of 1:9:30. For natural sciences, the ratio is 1:5:35, and for engineering 1:16:60 (see table 2 and figures 2.1 to 2.5).

The figures referred above encompass enrollments and graduates of all types of post secondary education regardless of their length of training. A better measure of the capacity to absorb and generate science and technology would be enrollments and graduates of the upper level of higher education, what in the Unesco classification are levels 6 and 7 (level 6 corresponds to a required minimum of three or four years post secondary education; level 7 entails at least one more year of study than level 6). The number of students in levels 6 and 7 per 100,000 population is 49, 1428, and 1592 for SSA, LA, and OECD respectively, resulting in a ratio of 1:29:32. The ratio for natural science is 1:11:23, and for engineering 1:72:72 (see table 3 and figures 3.1 to 3.5). These ratios deteriorate when considering graduates in the same fields. Graduates from levels 6 and 7 per 100,000 population are 5.2, 94.2, and 273.2 for SSA, LA, and OECD respectively, giving a ratio of 1:19:54. For the natural sciences the ratio is 1:4:31, and for engineering 1:74:166 (see table 4 and figures 4.1 to 4.5).

The distribution of enrollments by field does not reveal large differences between SSA, LA, and OECD. For example, 13.3% of the students in SSA were enrolled in the natural sciences compared with 7.4% in LA and 8.9% in OECD. Even in the field of engineering where SSA fares less well

than in other fields the percentages are 12.4%, 14.04% and 16% respectively for SSA, LA, and OECD (see table 5 and figure 5). The same lack of differences in the distributions of enrollments persists at levels 6 and 7 where the share of natural sciences are 13.7%, 6.3% and 9.5%, and the share of engineering are 9.95%, 15.16% and 12.52% for SSA, LA, and OECD respectively (see table 6 and figure 6).

The distribution of graduates by field also shows that the share of natural sciences is higher in the SSA than in LA and OECD (10.14%, 5.36%, and 9.11% respectively), although it is lower for engineering (8.7%, 13.93% and 13.63%) (see table 7 and figure 7). If we consider levels 6 and 7 only, the proportion of graduates in the natural sciences is way above those of LA and OECD (18.19% for SSA, 5.97% for LA, and 11.34% for OECD), although these proportions are reversed for engineering (3.45%, 16.49% and 12.8%) (see table 8 and figure 8).

The data presented above point to the following:

1. The proportion of the population in SSA enrolled in higher education, especially in the natural sciences and engineering, is appallingly low.
2. SSA countries graduate only 2.5 people a year per 100,000 population in the combined field of natural science and engineering compared with 95 in industrialized countries.
3. If we consider that a minimum of three or four years higher education is required to become a professional in science or engineering, SSA graduates only 1.2 people per year per 100,000

population in the natural sciences and engineering, compared with 65 in industrialized countries. The contrast is starker in the field of engineering: developed countries graduate 166 times more engineers per capita than do SSA countries. This discrepancy is due partly to the existing low efficiency - ratio of graduates to their entering class - in SSA.

4. However, contrary to a common belief that in SSA a smaller percentage of students choose natural sciences, there are only minor differences in the structure of enrollments and graduates by field of study.

Given this situation, if there is a need to produce more graduates in science and engineering, the options are:

- (a) increase total enrollments leaving the same structure of enrollments by field of study.
- (b) increasing efficiency (the ratio of graduates to entrants).
- (c) changing the enrollment structure to favor science and engineering.

Option (a) is the one being followed by most SSA countries. This option is doomed to failure for two reasons: budgetary constraints, and poor employment prospects for the vast majority of graduates from fields other than science and engineering.

Option (b) - an efficiency measure - should be exercised under any circumstances, but there is a limit beyond which it is impossible to increase graduates with a given stream of entrants. (Of course, if

efficiency is extremely low, say 10-15%, there is plenty of room to increase the number of graduates.)

Option (c) is the only realistic hope to increase the number of science and engineering graduates, since the present share is rather small and there is plenty of room to increase the share of science and engineering without impinging too much on the other fields, especially if higher education continues to expand.

The relative expansion of science and engineering enrollments requires even greater increase in the share of science and engineering in the budget because unit costs in these fields are usually higher than in the rest of higher education. Moreover, to implement option (b) in conjunction of option (c), may require increased expenditures to upgrade the level of scientific and mathematics knowledge of the pool of entrants to higher education when minimum proficiency skills in science and mathematics are lacking.

Enrollments: total by field and per 100,000 population

SUB-SAHARAN AFRICAN COUNTRIES

POPUL.	COUNTRY	ALL FIELD		FIELD NAT SC.		NAT SC.		ENG.		MED SC.		MED SC.		OTHER		OTHER	
		ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV
		1985	•	1985	•	1985	•	1985	•	1985	•	1985	•	1985	•	1985	•
4431	BDI	2753	82.95	207	4.88	194	4.39	0	0.00	292	5.93	2120	47.96				
1007	BWA	1434	142.40	194	19.27	0	0.00	0	0.00	0	0.00	1240	123.14				
38880	ETH	27388	81.17	4181	12.32	2363	6.99	1384	4.11	19450	57.75						
12700	GHA	1536	12.11	320	2.82	0	0.00	336	2.65	882	6.94						
8177	GIN	8801	170.00	3018	58.28	1084	20.94	458	8.85	4243	81.96						
18784	GNB	21758	115.82	1437	7.85	8482	45.18	1132	6.08	10708	58.99						
13311	MDZ	1442	10.88	89	0.82	541	4.08	162	1.22	670	5.08						
5700	MLI	1987	34.84	364	6.39	100	1.75	184	2.88	1369	23.84						
20882	SEN	33432	164.19	1271	6.34	2580	12.67	2011	9.88	27570	135.40						
6318	SEN	12711	201.25	2348	37.18	207	3.28	2486	39.38	7670	121.44						
20578	TZA	4014	19.70	247	1.21	870	3.29	413	2.08	2684	13.17						
14828	UGA	10108	69.08	934	6.39	1407	9.62	487	3.19	7298	49.88						
6242	ZMB	4880	74.98	890	11.06	844	8.72	302	4.84	3144	50.37						
AVERAGE:		89.18		13.36		9.30		7.00		59.53							
DEVIAT:		81.89		18.96		11.74		9.73		42.82							
MIN:		10.83		0.52		0.00		0.00		5.08							
MAX:		201.25		58.28		45.18		39.38		135.40							

MIDDLE INCOME SOUTH-AMERICAN COUNTRIES

POPUL.	COUNTRY	ALL FIELD		FIELD NAT SC.		NAT SC.		ENG.		MED SC.		MED SC.		OTHER		OTHER	
		ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV
		1985	•	1985	•	1985	•	1985	•	1985	•	1985	•	1985	•	1985	•
27318	COL	391490	1422.82	6477	23.84	98280	348.28	39904	148.08	249829	907.97						
2379	CRI	58398	3454.82	3968	168.37	5909	248.28	3130	131.87	45398	1908.20						
918	CUB	2328	258.59	187	18.19	287	28.88	98	10.88	1809	198.91						
2286	JAM	8128	227.02	1280	55.80	0	0.00	644	28.88	3222	142.69						
78108	MEX	1199100	1846.61	61178	81.46	284480	382.18	148710	198.01	724782	945.01						
3088	NIC	29001	948.38	1107	36.20	4832	148.20	4339	141.89	19028	622.07						
2099	PAN	58308	2847.34	2881	121.18	11547	583.71	3885	184.84	37380	1787.94						
5282	SLV	70499	1347.48	2182	41.70	13948	268.84	7118	138.06	47306	904.17						
381	URU	2751	788.78	27	7.89	28	6.88	110	31.34	2591	738.18						
1149	VTO	5184	278.37	897	80.88	529	48.04	0	0.00	1938	188.87						
2948	URY	87707	2488.09	5481	184.67	7715	234.94	18728	529.78	58788	1980.73						
18394	VEN	448080	2702.87	15923	97.13	84918	517.98	48448	283.43	295787	1804.06						
AVERAGE:		1487.88		74.88		282		181.78		1010.72							
DEVIAT:		870.78		58.28		188.41		140.49		687.75							
MIN:		227.02		7.89		0.00		0.00		142.69							
MAX:		2488.09		184.67		583.71		529.78		1980.73							

OECD COUNTRIES

POPUL.	COUNTRY	ALL FIELD		FIELD NAT SC.		NAT SC.		ENG.		MED SC.		MED SC.		OTHER		OTHER	
		ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV
		1985	•	1985	•	1985	•	1985	•	1985	•	1985	•	1985	•	1985	•
18899	ALB	870080	2407.77	82547	341.90	38273	236.01	23481	182.48	257799	1877.40						
7844	AUT	191880	2387.82	17821	233.42	19748	261.87	23808	312.73	130806	1730.10						
9886	BEL	247800	2811.18	20388	208.88	38029	385.88	42908	436.30	148210	1503.78						
34907	CAN	1137000	4824.88	84240	338.22	98227	396.98	79421	318.87	864712	3471.78						
8482	CHE	110110	1898.70	11818	182.27	21848	333.94	10248	188.10	86401	1024.39						
81421	DNK	1580280	2823.99	178880	290.70	309040	508.18	219780	387.78	842880	1372.27						
8114	DNK	118320	2274.54	7988	158.81	19802	381.38	17820	342.59	71330	1384.80						
38228	ESP	938130	2448.19	91887	240.29	119820	313.44	103620	271.09	619883	1821.41						
4843	FIN	127980	2631.71	18142	331.94	31872	681.29	18328	336.97	63828	1312.52						
56377	FRG	1032800	1831.42	134700	238.93	189040	282.10	181840	288.97	587120	1041.42						
9848	GRC	181900	1847.08	18424	188.77	33297	338.11	24849	249.28	107830	1092.91						
119289	JPN	2347800	1948.40	87028	58.20	412280	348.72	149810	128.45	1718888	1441.08						
14382	NLD	390320	2717.73	13784	45.84	64258	447.28	40138	279.44	272188	1898.20						
4129	NOR	94888	2292.52	7829	189.81	13889	336.89	10688	288.00	62307	1804.01						
3208	NZL	98408	3072.28	9788	308.49	18824	528.28	8805	212.48	64991	2029.07						
47279	TUR	489990	994.08	25089	53.07	90482	191.38	44043	93.18	310878	654.48						
AVERAGE:		2392.51		214.19		349.28		280.73		1348.35							
DEVIAT:		728.08		91.40		113.01		90.13		800.29							
MIN:		994.08		53.07		191.38		93.18		654.48							
MAX:		4824.83		341.90		651.29		438.30		3471.78							

• The actual number divided by 100,000 of the population

Source: Unesco Computer Tapes

Figure II-1: Enrollments by field per 100,000 population

Figure 1.1 : all field

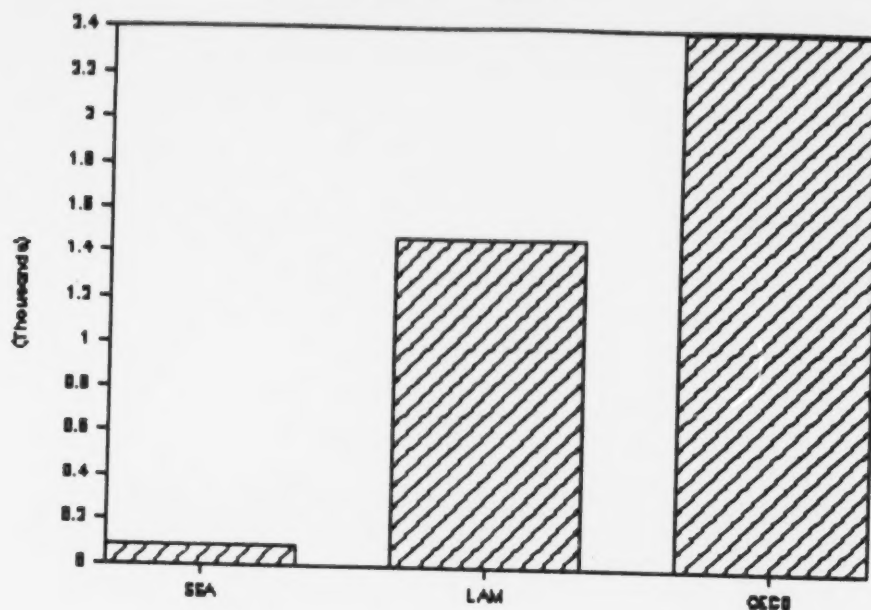


Figure 1.2 : natural sciences

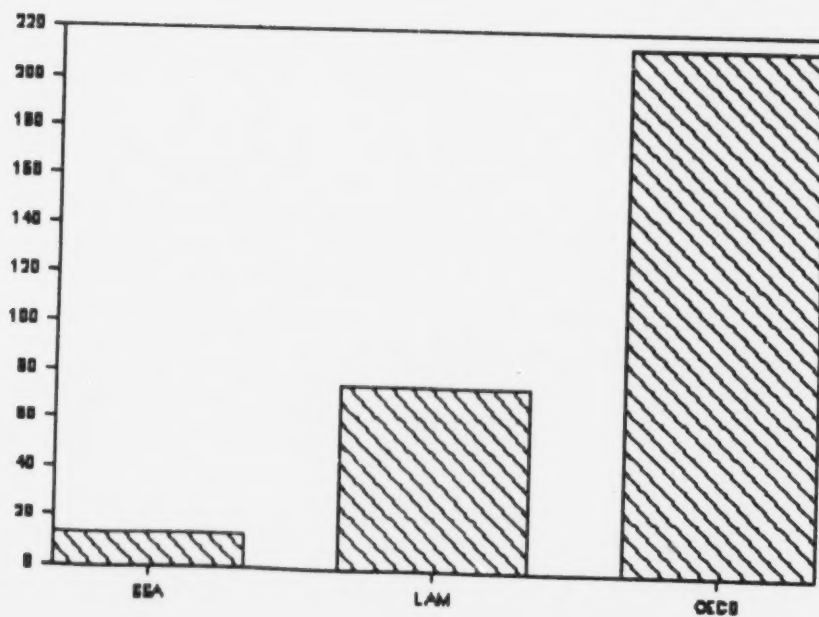


Figure 1.3 engineering

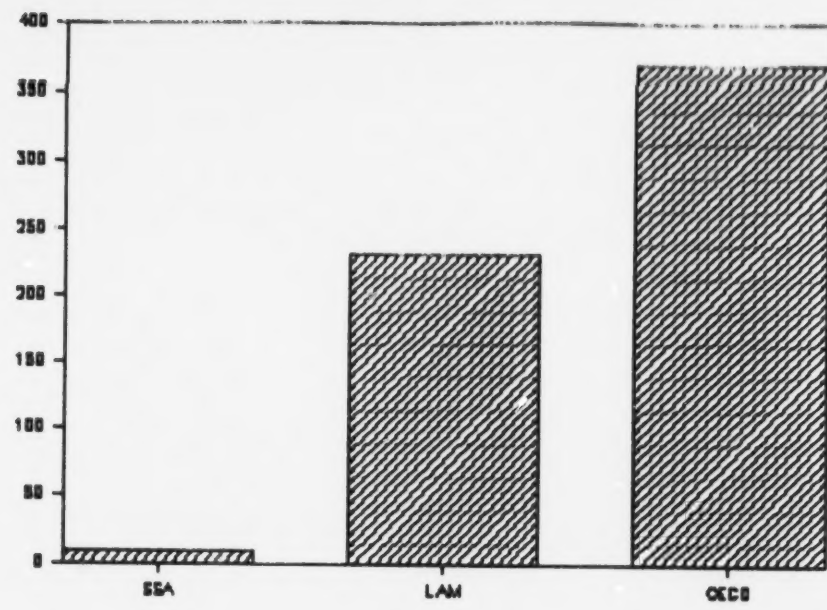


Figure 1.4 : medical sciences

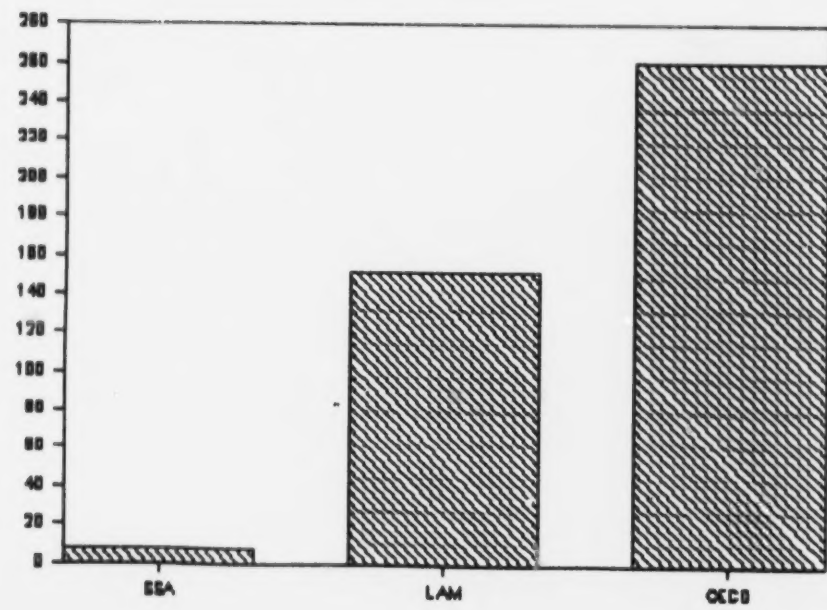
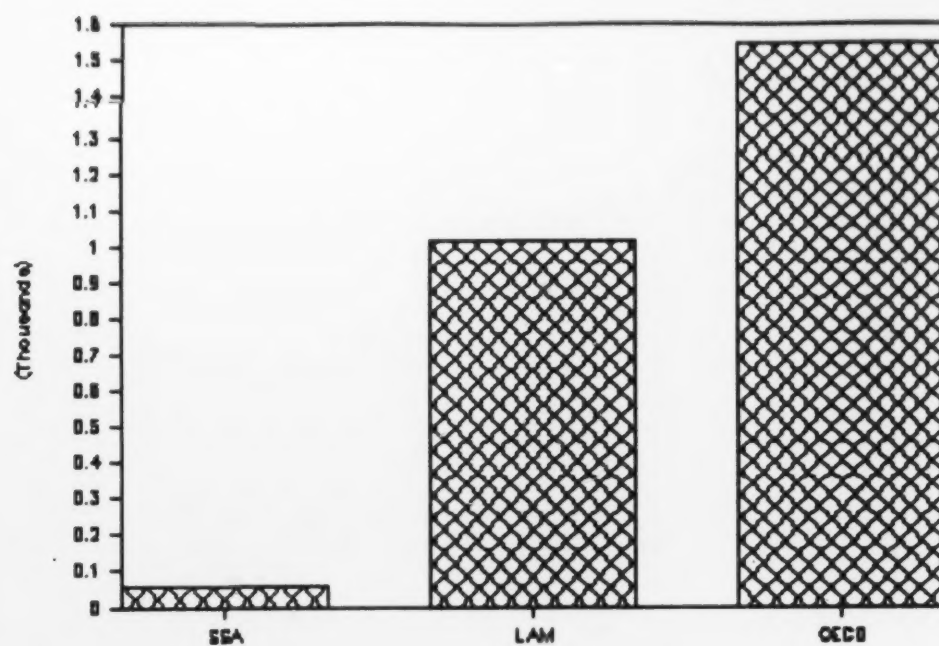


Figure 1.5 : other fields



Graduates: Total by field and per 100,000 population

SUB-SAHARAN AFRICAN COUNTRIES

POPUL.	COUNTRY	ALL FIELD		NAT. SC.		ENG.		MED. SC.		OTHER	
		ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV
1985		1985		1985		1985		1985		1985	
33480	ETH	5815	16.87	528	1.58	260	0.77	228	0.87	4803	13.87
12700	GHA	439	3.48	55	0.43	0	0.00	0	0.00	384	3.02
6429	HWI	1559	24.25	41	0.84	89	1.07	84	1.00	1385	21.54
5700	RWA	451	7.91	75	1.32	28	0.48	53	0.93	297	5.21
14825	UGA	2428	18.60	232	1.59	898	4.78	128	0.86	1374	9.39
AVERAGE:			13.78		1.11		1.41		0.89		10.57
DEVIAT:			7.31		0.48		1.71		0.38		8.59
MIN:			3.48		0.43		0.00		0.00		3.02
MAX:			24.25		1.59		4.78		1.00		21.54

MIDDLE INCOME SOUTH-AMERICAN COUNTRIES

POPUL.	COUNTRY	ALL FIELD		NAT. SC.		ENG.		MED. SC.		OTHER	
		ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV
1985		1985		1985		1985		1985		1985	
27515	COL	48738	177.13	785	2.78	10072	38.81	8029	21.91	31870	115.83
2379	CRI	4908	206.31	320	13.48	485	19.55	874	28.38	3449	144.98
918	QUY	711	77.45	39	4.25	88	7.08	38	3.92	571	82.20
2288	JAM	1183	51.51	178	7.79	0	0.00	138	5.99	854	37.82
75108	MEX	113080	150.53	4474	5.98	20040	28.68	19041	25.38	89498	92.53
3088	NIC	1636	53.50	112	3.68	227	7.42	285	8.87	1032	33.75
2089	PAN	3280	157.01	139	6.65	425	20.34	806	24.17	2211	105.84
5232	SLV	3825	73.11	44	0.84	887	18.95	454	8.68	2440	48.64
2988	URY	2832	88.68	130	4.38	275	9.27	1004	33.83	1223	41.21
18394	VEN	29408	179.37	1100	6.71	8417	39.14	3797	23.18	18092	110.38
AVERAGE:			121.48		5.68		18.30		18.39		79.11
DEVIAT:			55.34		3.28		12.28		10.04		37.58
MIN:			51.51		0.84		0.00		3.92		33.75
MAX:			206.31		13.48		39.14		33.83		144.98

OECD COUNTRIES

POPUL.	COUNTRY	ALL FIELD		NAT. SC.		ENG.		MED. SC.		OTHER	
		ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV	ALL LEV
1985		1985		1985		1985		1985		1985	
15599	AUS	73543	478.65	10485	68.09	8118	39.79	4813	29.36	53489	341.40
7549	AUT	14467	191.84	822	10.89	1271	18.84	2008	26.87	10988	137.34
9856	BEL	48928	498.36	4840	49.11	7398	78.08	8113	82.32	28275	296.88
24907	CAN	198480	798.88	19127	78.79	22897	91.98	20488	82.25	138470	545.91
6482	CHE	10108	158.88	1500	23.14	881	13.59	2010	31.01	8712	88.12
5114	DNK	18891	389.40	337	6.59	3113	80.87	3948	77.14	11498	224.79
38228	ESP	99984	261.55	7901	20.87	8731	22.84	18278	39.98	68077	178.08
4863	FIN	21808	448.39	2315	47.80	5742	118.08	8088	124.78	7880	157.93
88577	GBR	297780	528.19	40119	71.18	48820	83.08	81832	91.41	159309	282.58
9848	GRG	27309	277.31	2898	27.38	3712	37.89	2786	27.78	18188	184.48
119289	JPN	585570	491.09	15319	12.88	100480	84.28	30811	25.38	439490	368.68
3208	NZL	11274	351.98	1814	50.39	907	28.32	848	20.07	8110	253.20
47279	TUR	81098	129.23	2326	4.92	12998	27.49	5842	11.30	40430	85.81
234498	USA	1830800	780.53	181980	89.07	199300	84.99	182520	77.84	1284520	548.63
AVERAGE:			411.00		38.47		56.08		53.37		283.11
DEVIAT:			199.38		25.25		32.19		33.48		142.38
MIN:			129.23		4.92		13.59		11.30		85.81
MAX:			798.88		78.79		118.08		124.78		548.63

Source: Unesco Computer Tapes

Figure II-2: graduates by field per 100,000 population

Figure 2.1 : all field



Figure 2.2 : natural sciences

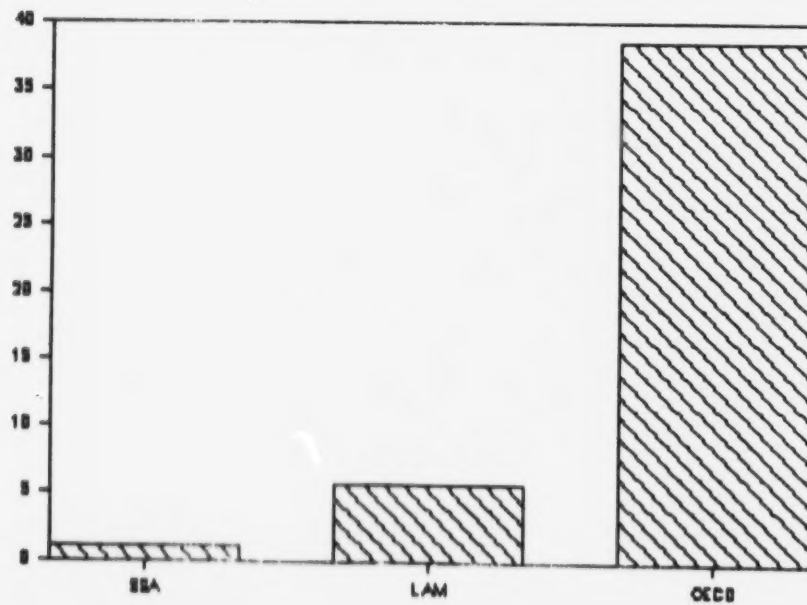


Figure 2.3 : engineering

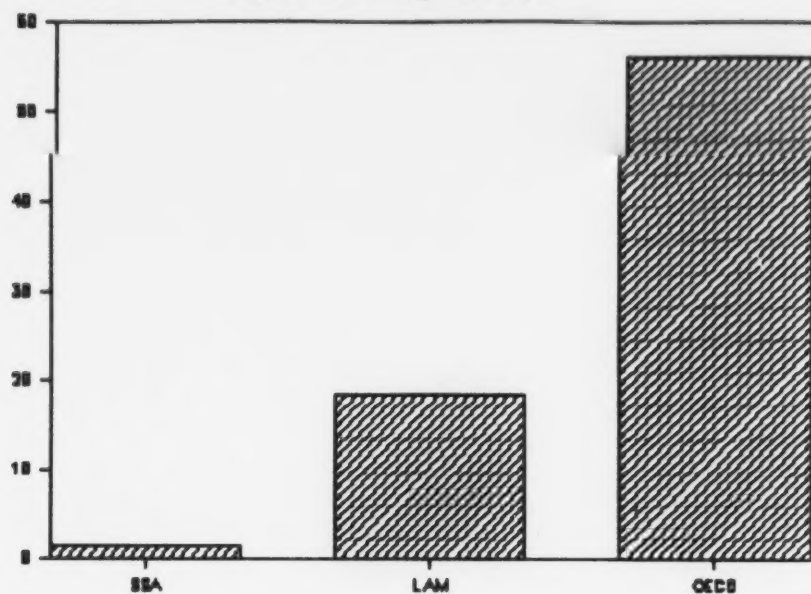


Figure 2.4 : medical sciences

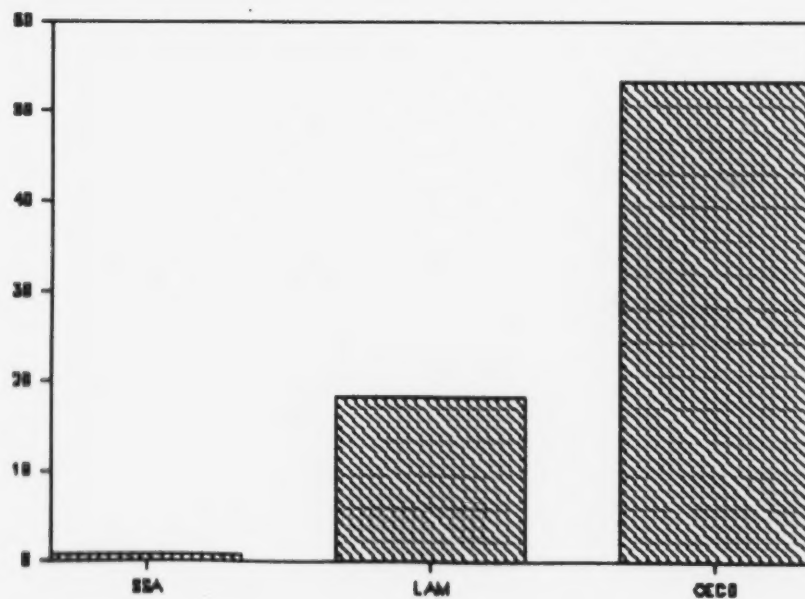
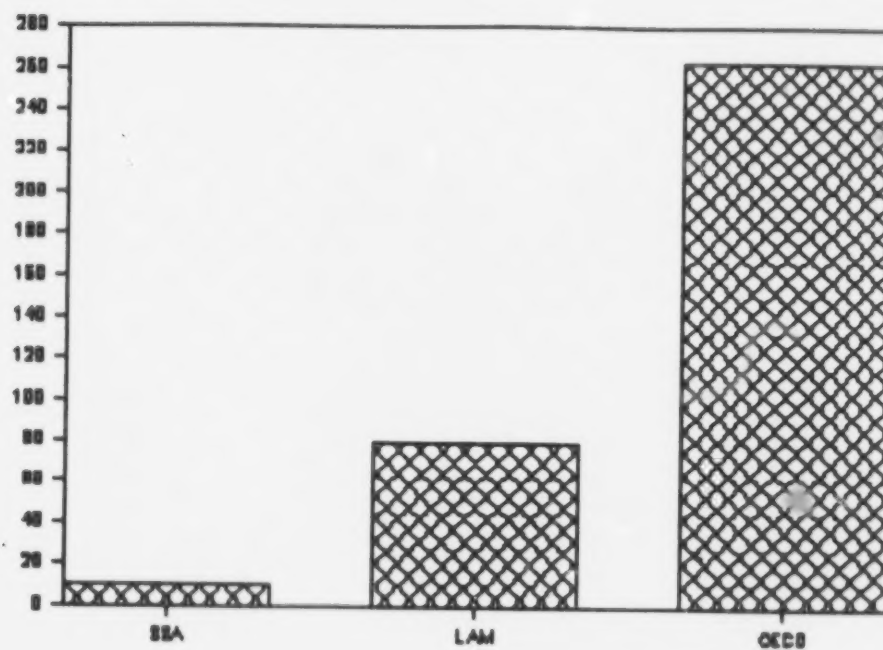


Figure 2.5 : other fields



Enrollments in levels 6+7: total by field and per 100,000 population

SUB-SAHARAN AFRICAN COUNTRIES

POPUL.	COUNTRY	ALL FIELD		FIELD NAT. SC.		NAT. SC.		ENG.		MED. SC.		OTHER	
		LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7
1985		1985		1985		1985		1985		1985		1985	
4421	BDI	2022	45.74	207	4.98	115	2.90	262	5.93	1436	32.53		
1007	BMA	1017	100.99	194	19.27	0	0.00	0	0.00	823	81.73		
33480	ETH	15486	45.98	3821	11.35	1079	3.20	1198	3.56	9388	27.87		
18784	KEM	9074	48.31	928	4.94	958	5.09	919	4.89	8271	33.36		
13311	KDZ	1442	10.83	89	0.83	541	4.06	182	1.22	870	5.03		
5700	MAA	1987	34.86	364	6.99	100	1.75	194	2.88	1359	23.84		
6318	SEN	4831	78.49	328	8.98	22	0.38	1488	28.56	2798	44.22		
20878	TZA	4014	19.70	247	1.21	670	3.29	413	2.03	2684	13.17		
14825	UGA	5178	35.39	923	6.31	256	1.75	487	3.19	3530	24.14		
8242	ZMB	4680	74.98	890	11.96	544	8.72	302	4.84	3144	50.37		
AVERAGE:			49.38		7.41		3.08		5.21		33.63		
DEVIAT:			28.18		8.21		2.40		8.35		20.40		
MIN:			10.83		0.82		0.00		0.00		5.03		
MAX:			100.99		19.27		8.72		28.56		61.73		

MIDDLE INCOME SOUTH-AMERICAN COUNTRIES

POPUL.	COUNTRY	ALL FIELD		FIELD NAT. SC.		NAT. SC.		ENG.		MED. SC.		OTHER	
		LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7
1985		1985		1985		1985		1985		1985		1985	
27515	COL	31680	1181.29	5078	18.48	78289	273.46	37344	135.72	301871	738.68		
2879	CRJ	8898	2454.32	3488	186.87	8909	248.38	3130	131.87	48996	1908.20		
918	CUY	1048	113.94	187	18.19	78	8.28	24	2.61	779	84.88		
75108	PER	1199178	1598.71	61178	81.48	264454	352.13	148713	198.01	724823	985.11		
3086	NIC	23448	786.81	906	29.68	3066	99.98	3489	114.09	15492	522.98		
3089	PAN	48098	2158.89	2515	120.39	5432	289.80	3821	182.91	38127	1585.78		
3232	BLV	80994	1185.79	2113	40.39	12514	239.18	6567	125.90	39780	780.32		
2988	URY	59688	3007.81	4786	181.25	7287	245.52	11171	376.38	36342	1224.48		
AVERAGE:			1428.15		79.82		217.06		158.40		973.17		
DEVIAT:			729.89		58.88		102.33		98.87		548.58		
MIN:			113.94		18.19		8.28		2.61		84.88		
MAX:			2454.32		186.87		352.13		376.38		1908.20		

OECD COUNTRIES

POPUL.	COUNTRY	ALL FIELD		FIELD NAT. SC.		NAT. SC.		ENG.		MED. SC.		OTHER	
		LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7	LEV 6+7
1985		1985		1985		1985		1985		1985		1985	
7549	AUT	177870	2388.21	17821	238.42	18782	248.80	22016	291.64	119451	1582.34		
9886	BEL	135740	1377.23	10890	107.45	25882	282.40	24489	248.47	74799	758.92		
34907	CAN	898472	3607.31	68244	274.00	53708	215.73	45983	184.54	730557	2933.14		
6488	CHE	78288	1129.79	11813	182.24	6998	107.98	10082	158.08	44370	684.51		
8114	DNK	89455	1749.22	7968	151.61	15492	306.84	8480	165.82	57315	1120.75		
38238	ESP	933989	2443.21	91857	241.29	119822	313.44	103802	270.75	618808	1618.73		
4863	FIN	91847	1884.58	13124	281.81	15678	320.30	8198	127.39	56782	1187.02		
86877	GER	878790	1204.02	115692	308.21	81963	145.38	43947	78.98	437738	778.48		
119289	JPN	1898788	1892.15	88748	58.47	874132	313.71	128925	108.11	1328968	1114.37		
14882	NLD	188860	1175.74	13764	95.84	22475	158.49	17190	119.89	115451	808.73		
4129	NOR	49819	1201.72	5000	121.09	6119	148.30	2908	70.38	38548	882.07		
3208	NZL	54388	1897.94	7601	237.31	4407	137.59	2488	78.99	39911	1248.05		
47279	TUR	418918	881.82	24726	52.30	72122	182.55	43286	91.52	278800	585.48		
AVERAGE:			1592.934		171.80		217.84		152.87		1173.36		
DEVIAT:			613.5670		75.70		78.83		73.02		596.23		
MIN:			881.82		52.30		107.98		70.38		585.48		
MAX:			3607.31		274.00		320.30		291.64		2933.14		

Source: Unesco Computer Tapes

Figure II-3: Enrollments in levels 6+7;
total by field and per 100,000 population

Figure 3.1 : all fields

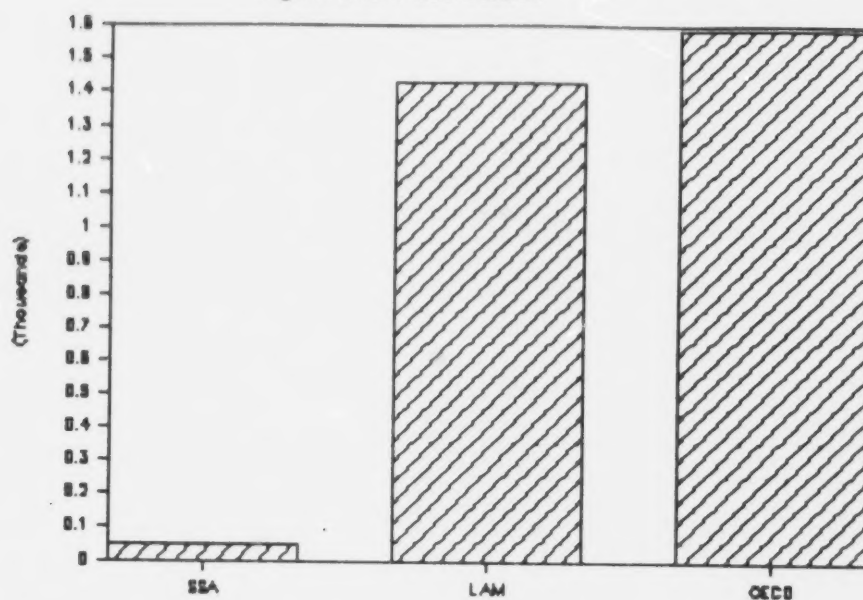


Figure 3.2 : natural sciences

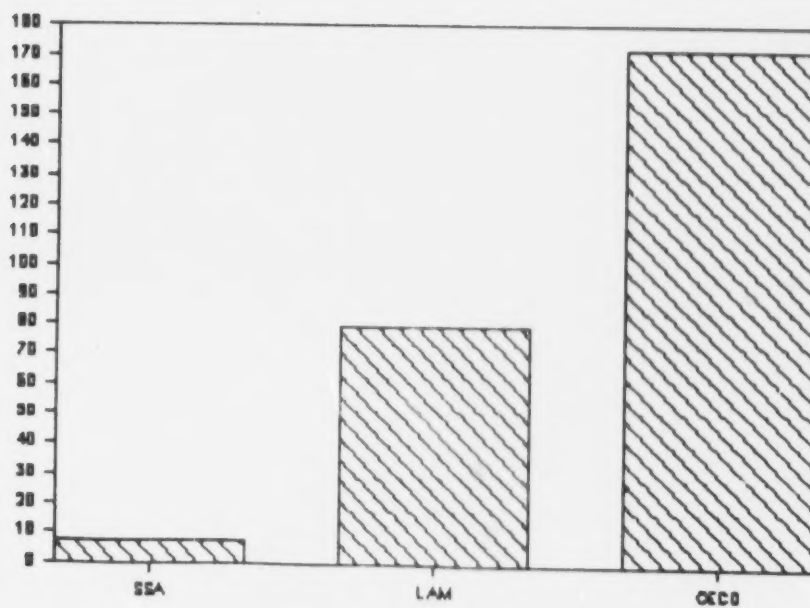


Figure 3.3 engineering

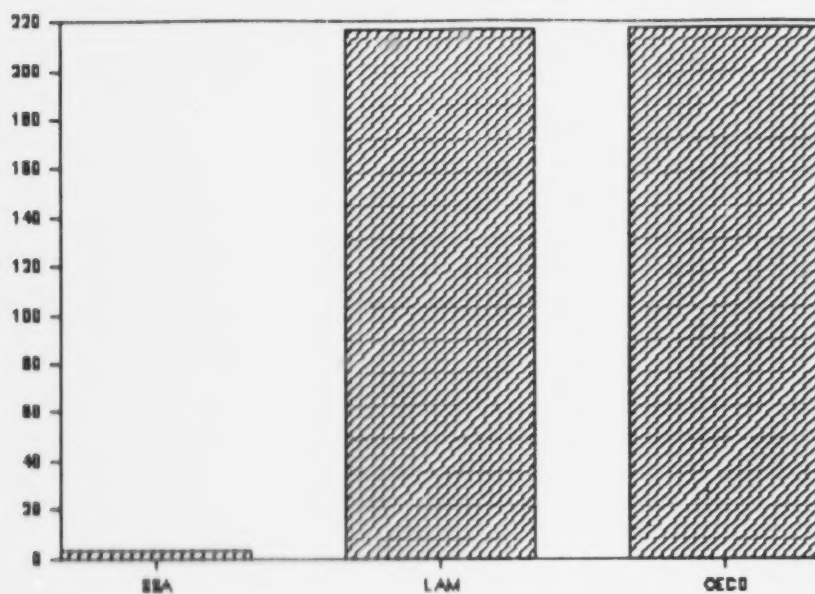


Figure 3.4 medical sciences

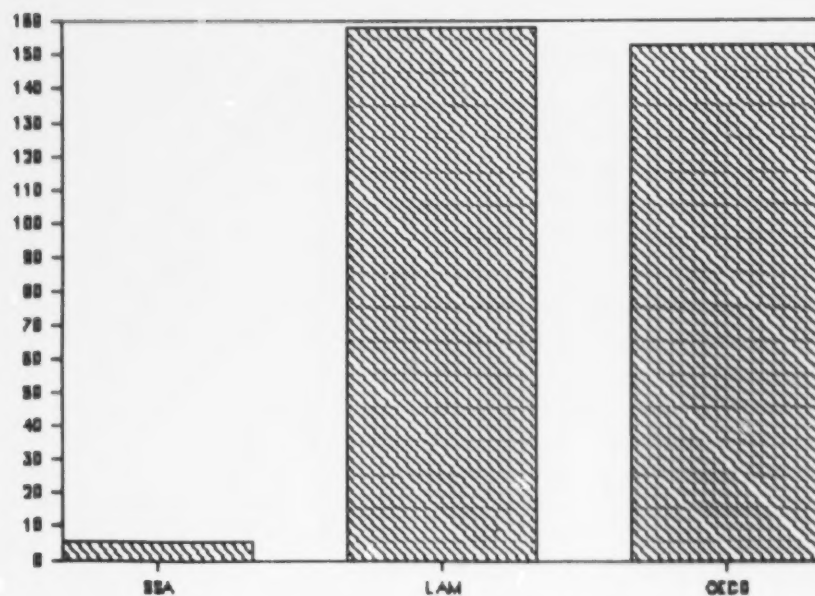
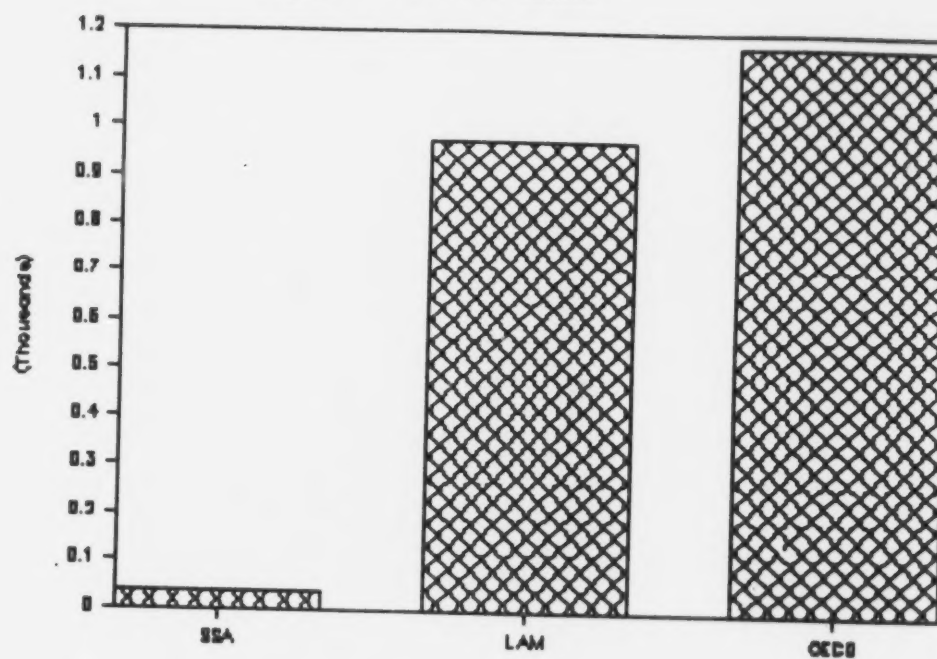


Figure 3.5 : other fields



Graduates from level 6+7: total by field and per 100,000 population

SUB-SAHARAN AFRICAN COUNTRIES

		ALL FIELD		FIELD NAT. SC.		NAT. SC.		ENG.		ENG.		MED. SC.		MED. SC.		OTHER		OTHER	
		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7	
POPUL.	COUNTRY	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*
33480	ETH	2067	8.14	488	1.45	138	0.40	183	0.48	1280	3.80								
12700	GHA	408	3.20	42	0.33	0	0.00	0	0.00	384	2.87								
6429	MWI	268	4.12	41	0.64	19	0.30	0	0.00	208	3.19								
8700	RWA	211	3.70	50	0.88	0	0.00	31	0.54	130	2.28								
14825	UGA	1301	8.90	232	1.59	48	0.31	123	0.84	900	6.15								
AVERAGE:			5.21		0.78		0.20		0.37		3.68								
DEVIAT.:			2.10		0.48		0.17		0.38		1.34								
MIN:			3.20		0.33		0.00		0.00		2.28								
MAX:			8.90		1.59		0.40		0.84		6.15								

MIDDLE INCOME SOUTH-AMERICAN COUNTRIES

		ALL FIELD		FIELD NAT. SC.		NAT. SC.		ENG.		ENG.		MED. SC.		MED. SC.		OTHER		OTHER	
		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7	
POPUL.	COUNTRY	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*
27815	COL	34328	132.08	483	1.88	6959	25.29	5398	19.61	23510	85.44								
2379	ORI	4197	178.42	282	11.88	402	18.90	570	23.98	2943	123.71								
918	OLV	208	22.11	39	4.28	34	3.70	0	0.00	130	14.16								
78108	MEX	113047	150.52	4474	5.98	20040	28.88	19041	25.38	89492	92.53								
3088	NIC	1001	32.73	107	3.50	107	3.50	102	3.34	885	22.40								
2089	PAN	2183	108.54	118	5.58	131	8.27	250	11.97	1688	79.75								
5232	SLV	1821	34.81	44	0.84	583	10.57	147	2.81	1077	20.58								
2988	URY	1843	82.10	20	0.87	267	9.00	588	19.14	988	33.29								
18994	VEN	21918	133.88	882	4.04	5170	31.54	3498	22.58	12388	75.58								
AVERAGE:			94.22		4.28		14.83		14.30		60.82								
DEVIAT.:			54.31		3.23		10.08		9.41		38.78								
MIN:			22.11		0.47		3.50		0.00		14.16								
MAX:			178.42		11.88		31.54		25.38		123.71								

OECD COUNTRIES

		ALL FIELD		FIELD NAT. SC.		NAT. SC.		ENG.		ENG.		MED. SC.		MED. SC.		OTHER		OTHER	
		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7		LEV 6+7	
POPUL.	COUNTRY	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*	1985	*
15369	ALB	48876	318.72	8734	58.83	5108	38.22	3212	20.90	31628	205.77								
7849	AUT	9886	128.28	822	10.89	1008	13.38	1689	22.11	8188	81.93								
9888	BEL	23711	240.87	2308	28.40	4481	48.48	3183	32.09	13781	139.82								
24907	CAN	138718	558.94	14812	59.47	11074	44.48	9887	39.49	102988	418.52								
8488	CHE	9141	141.02	1342	20.70	881	13.89	2010	31.01	4908	78.72								
5114	DNK	10209	199.63	337	8.89	1702	35.28	1710	33.44	8480	129.32								
38228	ESP	99182	289.40	7901	20.87	8731	22.84	15234	39.88	87298	178.04								
4888	FIN	9887	198.17	1378	28.27	1280	25.70	1184	23.94	5848	120.25								
88877	GER	180841	320.24	32014	58.79	23188	41.08	9807	18.88	115882	208.51								
9848	GRC	18081	182.99	2893	27.38	1813	18.41	1794	18.22	9751	99.02								
119889	JPN	402217	337.28	15181	12.73	84973	71.25	23072	19.35	278991	233.94								
3808	NEL	8971	280.08	1814	50.99	858	28.72	842	20.04	5889	182.92								
47279	TUR	48547	98.48	2280	4.78	8748	18.80	5207	11.01	30348	64.18								
284498	USA	1373740	588.83	144820	81.78	133881	58.97	113381	48.34	981978	418.78								
AVERAGE:			278.28		31.47		33.20		26.90		181.68								
DEVIAT.:			141.41		20.31		18.41		10.28		108.33								
MIN:			98.48		4.78		13.38		11.01		64.18								
MAX:			588.83		81.78		71.25		48.34		418.78								

Source: Unesco Computer Tapes

Figure II-4: graduates from levels 6+7;
total by field and per 100,000 population

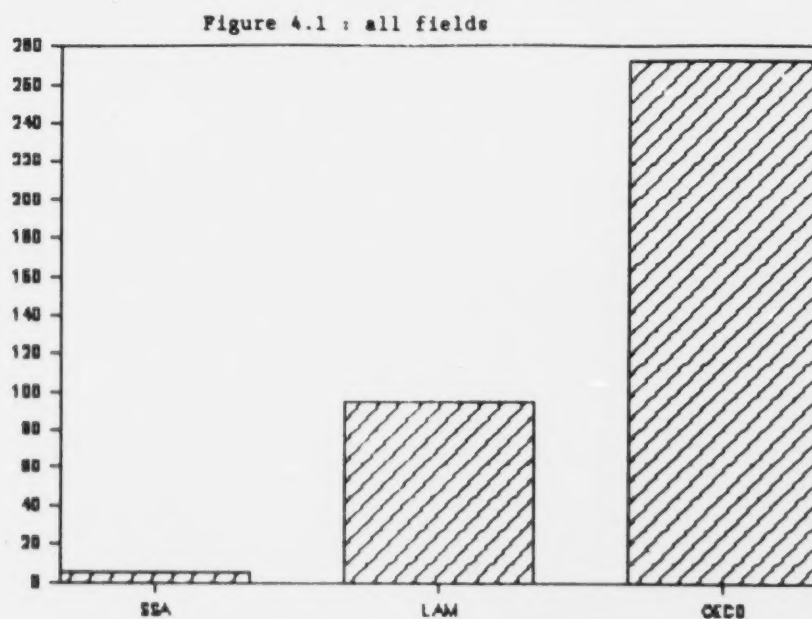


Figure 4.2 : natural sciences

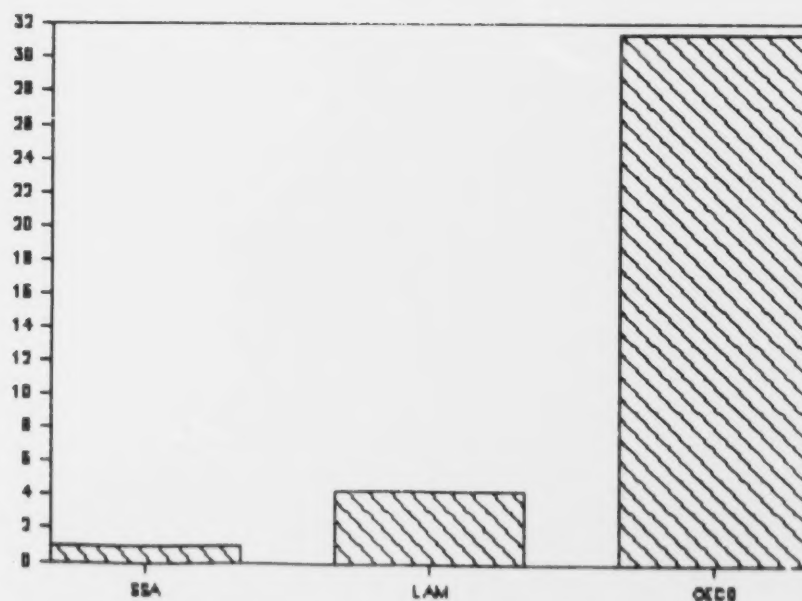


Figure 4.3 engineering

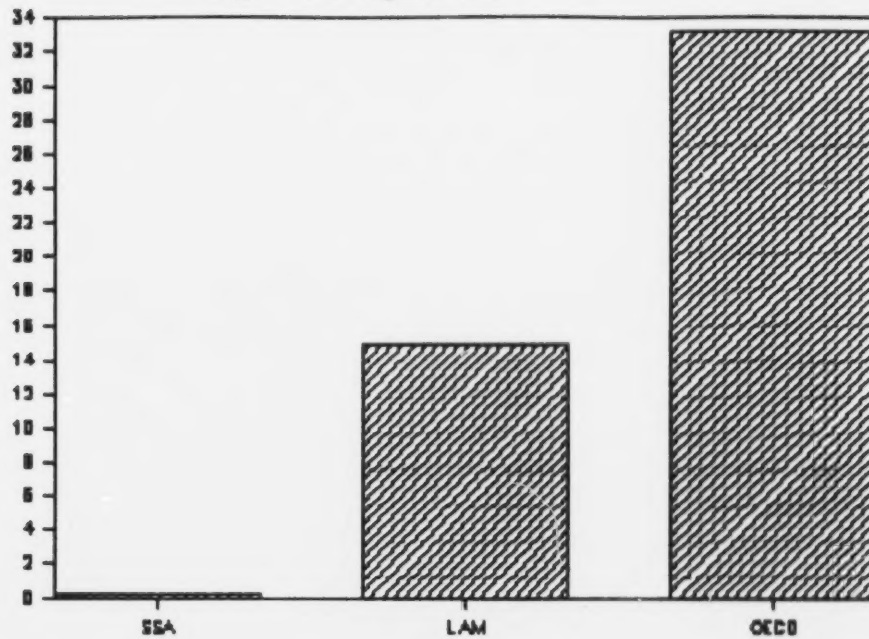


Figure 4.4 :medical sciences

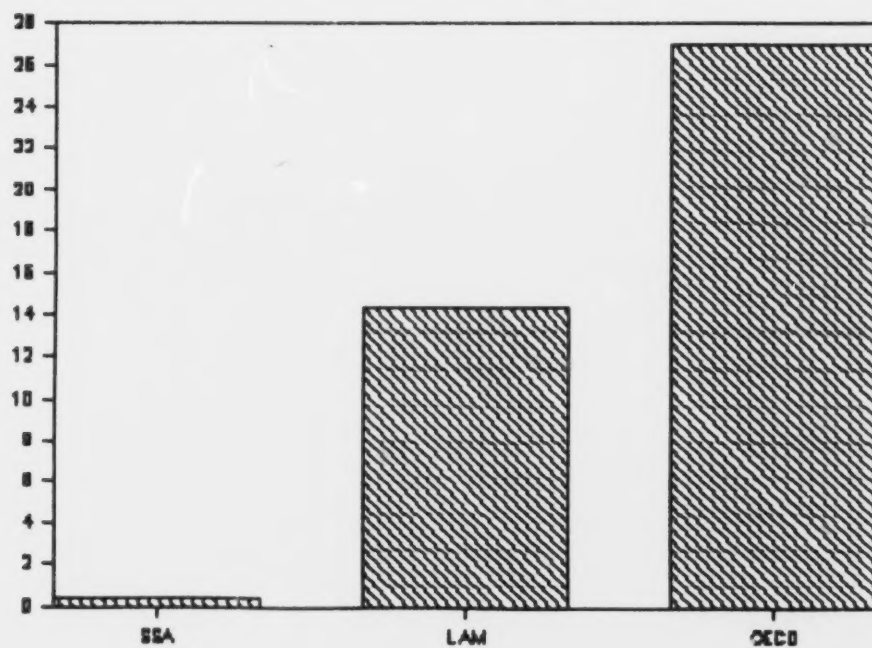
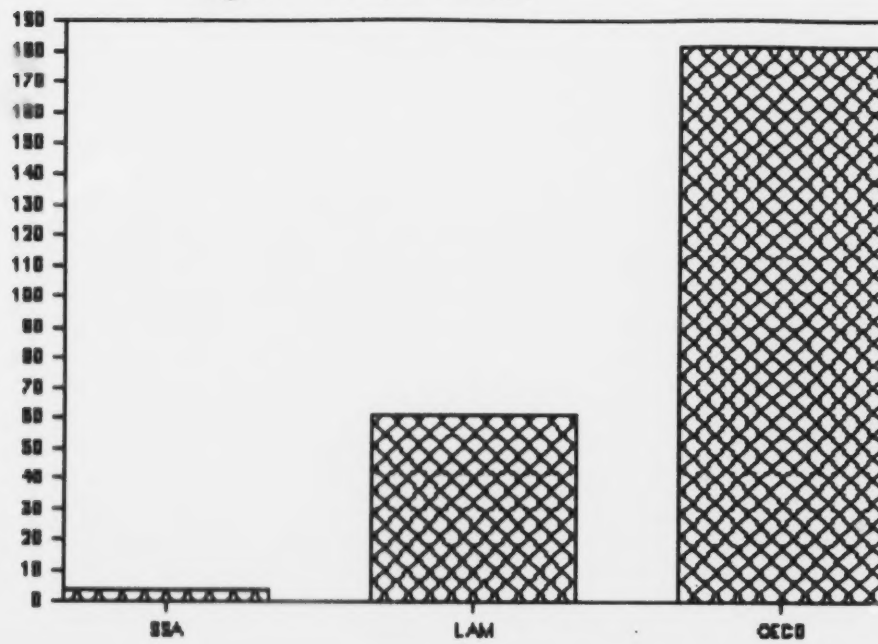


Figure 4.5 : other fields



Distribution of enrollments by field in percent

SUB-SAHARAN AFRICAN COUNTRIES

	NAT. SC.		ENG.		MED. SC.		OTHER		TOTAL
	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	
COUNTRY	1985	%	1985	%	1985	%	1985	%	
BDI	207	7.44%	194	8.97%	282	9.41%	2120	78.18%	100.00%
BFA	194	13.52%	0	0.00%	0	0.00%	1240	86.47%	100.00%
ETH	4151	15.18%	2353	8.81%	1384	5.08%	19480	71.15%	100.00%
GHA	320	20.81%	0	0.00%	336	21.88%	882	57.35%	100.00%
GIN	3018	34.27%	1084	12.32%	458	5.20%	4243	48.21%	100.00%
KEN	1437	8.81%	8482	38.99%	1132	5.20%	10708	49.20%	100.00%
KOZ	89	4.79%	841	37.82%	182	11.22%	870	48.48%	100.00%
MVA	384	18.82%	100	5.03%	184	8.25%	1359	68.39%	100.00%
SDH	1271	3.80%	2580	7.72%	2011	6.02%	27570	82.47%	100.00%
SEN	2348	18.47%	207	1.63%	2488	19.58%	7870	60.34%	100.00%
TZA	247	8.15%	870	18.89%	413	10.29%	2884	88.87%	100.00%
UGA	934	9.24%	1407	13.93%	487	4.82%	7285	72.21%	100.00%
ZMB	890	14.74%	544	11.82%	302	6.45%	3144	87.18%	100.00%
AVERAGE:		13.38%		12.39%		8.70%		68.57%	
DEVIAT:		8.15%		12.10%		5.84%		12.25%	
MIN:		3.80%		0.00%		0.00%		48.48%	
MAX:		34.27%		38.99%		21.88%		88.87%	

MIDDLE INCOME SOUTH-AMERICAN COUNTRIES

	NAT. SC.		ENG.		MED. SC.		OTHER		TOTAL
	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	
COUNTRY	1985	%	1985	%	1985	%	1985	%	
COL	6477	1.88%	95280	24.34%	39904	10.19%	249829	63.81%	100.00%
CRI	3958	8.78%	5909	10.12%	3130	5.38%	48348	77.74%	100.00%
GLY	187	7.17%	237	10.18%	98	4.21%	1828	78.44%	100.00%
JAH	1280	24.88%	0	0.00%	844	12.58%	3223	62.88%	100.00%
MEX	81178	8.10%	264440	22.08%	148710	12.40%	724782	60.44%	100.00%
NIC	1107	3.82%	4532	15.83%	4339	14.98%	19028	68.59%	100.00%
PAN	2531	4.88%	11587	20.92%	3888	8.97%	37380	87.54%	100.00%
SLV	2182	8.10%	13893	19.71%	7118	10.10%	47308	87.10%	100.00%
SRB	27	0.98%	28	0.84%	110	4.00%	2891	94.18%	100.00%
TTD	897	22.03%	529	18.72%	0	0.00%	1938	81.25%	100.00%
URY	5481	8.25%	7718	8.80%	15729	17.63%	58788	67.03%	100.00%
VEN	15923	3.89%	84918	19.17%	48485	10.49%	298787	68.78%	100.00%
AVERAGE:		7.47%		14.04%		9.10%		69.40%	
DEVIAT:		7.33%		7.72%		4.92%		9.23%	
MIN:		0.98%		0.00%		0.00%		60.44%	
MAX:		24.88%		24.34%		17.63%		94.18%	

OECD COUNTRIES

	NAT. SC.		ENG.		MED. SC.		OTHER		TOTAL
	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	ALL LEV.	
COUNTRY	1985	%	1985	%	1985	%	1985	%	
AUS	52547	14.20%	36273	9.80%	23431	6.33%	257799	69.67%	100.00%
AUT	17821	9.20%	19748	10.31%	23608	12.32%	150608	88.17%	100.00%
BEL	20888	8.22%	36029	14.58%	42908	17.33%	148210	59.88%	100.00%
CAN	84240	7.47%	98827	8.75%	78421	7.08%	884712	78.73%	100.00%
CHE	11815	10.73%	21648	19.68%	10248	9.31%	88401	80.30%	100.00%
DEU	178850	11.52%	309040	19.94%	219750	14.18%	842880	54.37%	100.00%
DNK	7948	8.65%	19802	18.77%	17520	18.08%	71330	81.32%	100.00%
ESP	91687	9.82%	119820	12.81%	103820	11.08%	619833	64.28%	100.00%
FIN	18142	12.81%	31672	24.75%	18338	12.77%	63828	49.87%	100.00%
GBR	134700	13.08%	159040	15.40%	151840	14.89%	587120	58.88%	100.00%
GRG	18424	9.03%	33297	18.31%	24849	13.50%	107680	58.17%	100.00%
JPN	87025	2.88%	412280	17.58%	149810	6.37%	1718888	73.21%	100.00%
NLD	13784	3.53%	84238	18.48%	40138	10.28%	272188	69.73%	100.00%
NOR	7829	8.27%	13889	14.65%	10653	11.25%	62307	65.82%	100.00%
NZL	9788	9.94%	18824	17.10%	8808	8.92%	84991	88.04%	100.00%
TUR	25089	5.34%	90482	19.25%	44043	9.37%	310878	68.04%	100.00%
AVERAGE:		8.92%		18.00%		11.11%		62.97%	
DEVIAT:		3.13%		4.08%		3.29%		8.85%	
MIN:		2.88%		8.75%		6.33%		49.87%	
MAX:		14.20%		24.75%		17.33%		78.73%	

Source: Unesco Computer Tapes

Figure II-5: Distribution of enrollments by field in percent

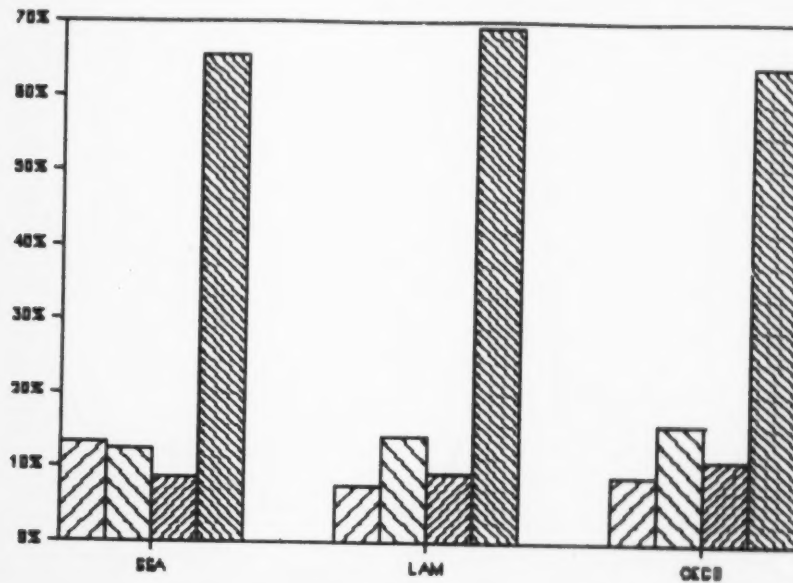
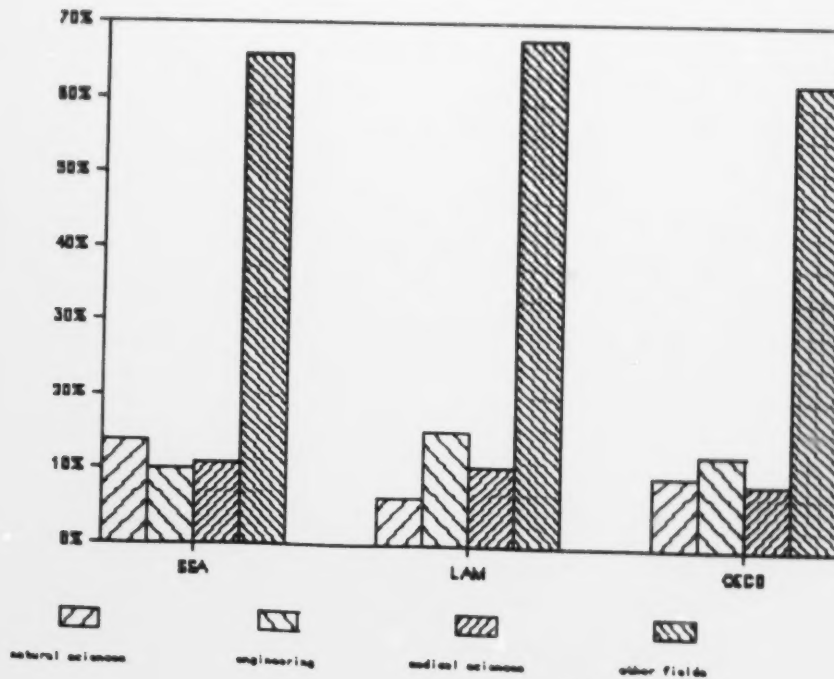


Figure 6: Distribution of enrollments in levels 6+7 by field in percent



Distribution of enrollments in levels 6+7 by fields in percent

SUB-SAHARAN AFRICAN COUNTRIES

	NAT. SC. LEV 6+7	NAT. SC. LEV 6+7	ENG. LEV 6+7	ENG. LEV 6+7	MED. SC. LEV 6+7	MED. SC. LEV 6+7	OTHER LEV 6+7	OTHER LEV 6+7	TOTAL
COUNTRY	1965	%	1965	%	1965	%	1965	%	
BDI	207	10.24%	115	5.69%	262	12.94%	1458	71.12%	100.00%
BWA	194	19.08%	0	0.00%	0	0.00%	822	80.92%	100.00%
ETH	3821	24.87%	1079	8.97%	1198	7.74%	9388	80.82%	100.00%
KEN	928	10.23%	958	10.54%	919	10.13%	8271	89.11%	100.00%
MDZ	89	4.79%	541	37.52%	182	11.23%	870	48.48%	100.00%
RWA	364	18.32%	100	5.03%	184	8.28%	1359	68.39%	100.00%
SEN	528	10.03%	22	0.44%	1488	30.80%	2768	57.81%	100.00%
TZA	247	8.15%	870	18.89%	413	10.29%	2684	68.87%	100.00%
UGA	923	17.83%	258	4.95%	487	9.02%	3830	68.20%	100.00%
ZMB	590	14.74%	544	11.82%	302	6.48%	3144	67.18%	100.00%
AVERAGE:		13.70%		9.95%		10.69%		65.67%	
DEVIAT.:		5.97%		10.38%		7.48%		8.68%	
MIN:		4.79%		0.00%		0.00%		48.48%	
MAX:		24.87%		37.52%		30.80%		80.92%	

MIDDLE INCOME SOUTH-AMERICAN COUNTRIES

	NAT. SC. LEV 6+7	NAT. SC. LEV 6+7	ENG. LEV 6+7	ENG. LEV 6+7	MED. SC. LEV 6+7	MED. SC. LEV 6+7	OTHER LEV 6+7	OTHER LEV 6+7	TOTAL
COUNTRY	1965	%	1965	%	1965	%	1965	%	
COL	5078	1.59%	75239	23.58%	37344	11.89%	301871	63.18%	100.00%
CRI	3988	8.78%	5909	10.12%	3130	5.34%	48898	77.74%	100.00%
GUI	187	15.97%	78	7.27%	24	2.29%	779	74.47%	100.00%
MEX	81178	5.10%	284489	22.08%	148713	12.40%	724885	60.44%	100.00%
NIC	908	3.88%	3088	13.04%	3499	14.88%	18492	68.22%	100.00%
PAH	2815	5.58%	5832	12.49%	3821	8.47%	38137	78.46%	100.00%
SLV	2113	3.48%	12514	20.82%	6587	10.80%	34780	68.22%	100.00%
URY	4788	8.03%	7287	12.23%	11171	18.78%	38842	60.94%	100.00%
AVERAGE:		8.30%		15.18%		10.58%		67.97%	
DEVIAT.:		4.10%		5.64%		4.88%		6.18%	
MIN:		1.59%		7.27%		2.29%		60.44%	
MAX:		15.97%		23.58%		18.78%		77.74%	

OECD COUNTRIES

	NAT. SC. LEV 6+7	NAT. SC. LEV 6+7	ENG. LEV 6+7	ENG. LEV 6+7	MED. SC. LEV 6+7	MED. SC. LEV 6+7	OTHER LEV 6+7	OTHER LEV 6+7	TOTAL
COUNTRY	1965	%	1965	%	1965	%	1965	%	
AUT	17821	9.91%	18782	10.58%	22018	12.38%	119481	67.18%	100.00%
BEL	10890	7.80%	28882	19.05%	24489	18.04%	74799	58.10%	100.00%
CAN	68244	7.80%	53708	5.98%	48463	5.12%	730657	81.31%	100.00%
CHE	11813	18.13%	8998	9.58%	10082	13.72%	44870	60.54%	100.00%
DNK	7988	8.91%	15892	17.54%	8480	9.48%	57318	64.07%	100.00%
ESP	91857	9.83%	119822	12.83%	108802	11.08%	818808	84.28%	100.00%
FIN	13124	14.32%	18878	17.00%	8198	8.74%	58782	61.92%	100.00%
FR	115892	17.04%	81968	12.07%	43397	6.39%	487738	64.44%	100.00%
JPN	68748	3.82%	374132	19.70%	128928	6.79%	1328988	69.94%	100.00%
NLD	13784	8.15%	22475	13.31%	17190	10.18%	115481	68.36%	100.00%
NOR	5000	10.08%	8119	12.33%	2908	8.88%	38848	71.74%	100.00%
NZL	7801	13.98%	4407	8.10%	2448	4.53%	39911	73.39%	100.00%
TUR	24728	5.93%	72122	17.30%	43288	10.38%	278800	66.39%	100.00%
AVERAGE:		9.51%		12.52%		8.62%		62.20%	
DEVIAT.:		4.57%		5.31%		4.34%		18.28%	
MIN:		3.52%		5.98%		4.58%		58.10%	
MAX:		17.04%		19.70%		18.04%		81.31%	

Source: Unesco Computer Tapes

Distribution of graduates by field in percent

SUB-SAHARAN AFRICAN COUNTRIES

	NAT. SC. ALL LEV	NAT. SC. ALL LEV	ENG. ALL LEV	ENG. ALL LEV	MED. SC. ALL LEV	MED. SC. ALL LEV	OTHER ALL LEV	OTHER ALL LEV	TOTAL
COUNTRY	1985	%	1985	%	1985	%	1985	%	%
ETH	526	9.37%	260	4.63%	226	4.02%	4608	81.98%	100.00%
GHA	55	12.53%	0	0.00%	0	0.00%	384	87.47%	100.00%
MWI	41	2.63%	89	4.43%	84	4.11%	1386	88.84%	100.00%
RWA	75	16.63%	26	5.76%	53	11.75%	297	65.85%	100.00%
UGA	232	9.56%	696	28.67%	126	5.19%	1374	56.59%	100.00%
AVERAGE:		10.14%		8.70%		5.01%		74.15%	
DEVIAT:		4.59%		10.18%		3.80%		12.74%	
MIN:		2.63%		0.00%		0.00%		56.59%	
MAX:		16.63%		28.67%		11.75%		88.84%	

MIDDLE INCOME SOUTH-AMERICAN COUNTRIES

	NAT. SC. ALL LEV	NAT. SC. ALL LEV	ENG. ALL LEV	ENG. ALL LEV	MED. SC. ALL LEV	MED. SC. ALL LEV	OTHER ALL LEV	OTHER ALL LEV	TOTAL
COUNTRY	1985	%	1985	%	1985	%	1985	%	%
COL	785	1.87%	10072	20.67%	6029	12.37%	31670	65.39%	100.00%
CRI	320	6.52%	468	9.47%	874	13.79%	3449	70.27%	100.00%
QUY	39	5.49%	68	9.14%	36	5.08%	571	80.31%	100.00%
JAM	178	15.13%	0	0.00%	138	11.44%	854	73.43%	100.00%
MEX	4474	3.96%	20040	17.73%	19041	16.64%	89466	81.47%	100.00%
NIC	112	8.65%	227	13.68%	265	16.20%	1082	63.06%	100.00%
PAN	139	4.24%	425	12.96%	508	15.40%	2211	67.41%	100.00%
SLV	44	1.15%	867	23.19%	484	11.87%	2440	65.79%	100.00%
URY	130	4.94%	275	10.45%	1004	38.18%	1228	46.47%	100.00%
VEN	1100	3.74%	6417	21.82%	3797	12.91%	18092	61.52%	100.00%
AVERAGE:		5.36%		13.93%		15.40%		65.32%	
DEVIAT:		3.70%		8.77%		8.21%		8.43%	
MIN:		1.15%		0.00%		5.08%		46.47%	
MAX:		15.13%		23.19%		38.18%		80.31%	

OECD COUNTRIES

	NAT. SC. ALL LEV	NAT. SC. ALL LEV	ENG. ALL LEV	ENG. ALL LEV	MED. SC. ALL LEV	MED. SC. ALL LEV	OTHER ALL LEV	OTHER ALL LEV	TOTAL
COUNTRY	1985	%	1985	%	1985	%	1985	%	%
AUS	10465	14.22%	8116	8.31%	4519	6.13%	52489	71.33%	100.00%
AUT	822	5.68%	1271	9.79%	2008	13.67%	10868	71.67%	100.00%
BEL	4840	9.66%	7398	15.21%	8113	16.68%	28278	58.15%	100.00%
CAN	19127	9.64%	22897	11.54%	20466	10.32%	135970	68.51%	100.00%
CHE	1500	14.86%	861	8.72%	2010	19.90%	8712	86.54%	100.00%
DNK	337	1.78%	3113	16.46%	3945	20.88%	11496	60.88%	100.00%
ESP	7901	7.90%	8731	8.73%	15275	15.28%	68077	68.09%	100.00%
FIN	2315	10.62%	5742	26.33%	6068	27.63%	7660	35.22%	100.00%
GBR	40119	18.47%	48520	15.72%	51532	17.31%	184809	65.50%	100.00%
GRG	2893	9.86%	3712	13.59%	2736	10.02%	18168	66.53%	100.00%
JPN	15319	2.82%	100450	17.15%	30211	5.16%	439490	78.07%	100.00%
NZL	1614	14.32%	907	8.05%	648	5.70%	8110	71.94%	100.00%
TUR	2328	3.81%	12998	21.27%	5342	8.74%	40480	68.17%	100.00%
USA	181960	8.86%	194300	10.89%	182520	9.97%	1284520	70.27%	100.00%
AVERAGE:		9.11%		13.63%		13.41%		63.86%	
DEVIAT:		4.19%		5.28%		6.36%		10.06%	
MIN:		1.78%		8.05%		5.16%		35.22%	
MAX:		14.86%		26.33%		27.63%		78.07%	

Source: Unesco Computer Tapes

Figure II-7: distribution of graduates by field in percent

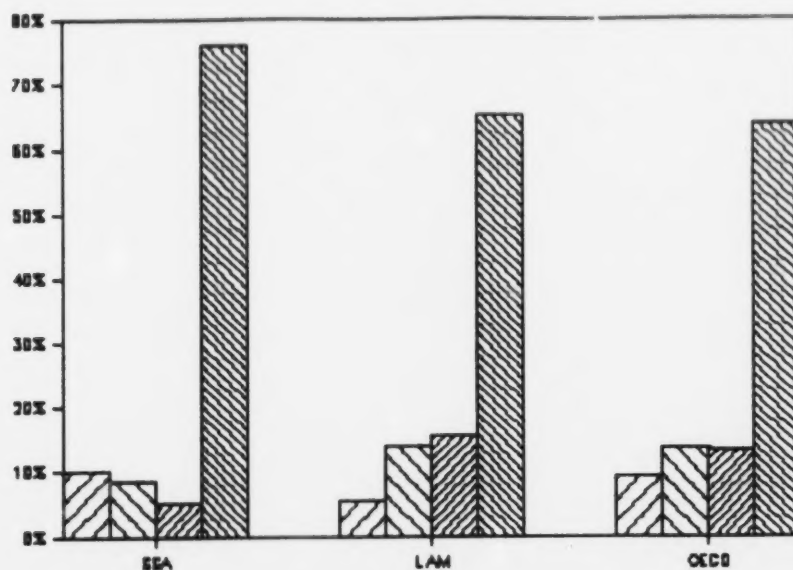
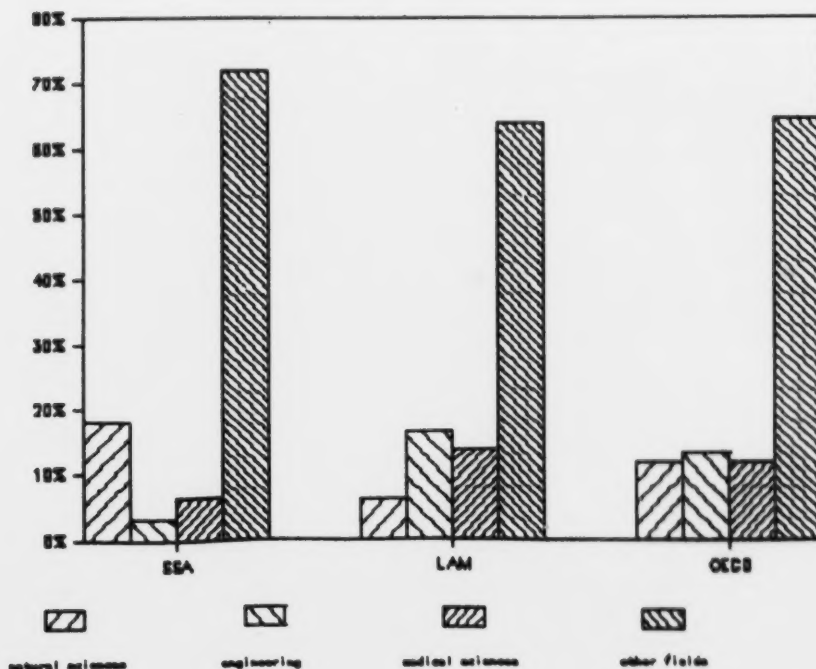


Figure 8: Distribution of graduates from levels 6+7 by field in percent



Distribution of graduates from level 6+7 by field in percent

SUB-SAHARAN AFRICAN COUNTRIES

	NAT. SC. LEV 6+7	NAT. SC. LEV 6+7	ENG. LEV 6+7	ENG. LEV 6+7	MED. SC. LEV 6+7	MED. SC. LEV 6+7	OTHER LEV 6+7	OTHER LEV 6+7	TOTAL
COUNTRY	1985	%	1985	%	1985	%	1985	%	%
ETH	488	23.61%	138	6.58%	183	7.89%	1280	61.93%	100.00%
GHA	42	10.34%	0	0.00%	0	0.00%	384	89.66%	100.00%
MWI	41	15.47%	19	7.17%	0	0.00%	205	77.36%	100.00%
RWA	50	23.70%	0	0.00%	31	14.69%	130	61.61%	100.00%
UGA	232	17.63%	48	3.54%	123	9.45%	900	69.18%	100.00%
AVERAGE:		18.19%		3.46%		8.41%		71.95%	
DEVIAT.:		5.07%		3.08%		5.70%		10.56%	
MIN:		10.34%		0.00%		0.00%		61.61%	
MAX:		23.70%		7.17%		14.69%		89.66%	

MIDDLE INCOME SOUTH-AMERICAN COUNTRIES

	NAT. SC. LEV 6+7	NAT. SC. LEV 6+7	ENG. LEV 6+7	ENG. LEV 6+7	MED. SC. LEV 6+7	MED. SC. LEV 6+7	OTHER LEV 6+7	OTHER LEV 6+7	TOTAL
COUNTRY	1985	%	1985	%	1985	%	1985	%	%
COL	463	1.27%	8959	19.18%	5398	14.85%	23510	64.72%	100.00%
CRI	282	8.72%	402	9.58%	570	13.58%	2943	70.12%	100.00%
GLY	39	19.21%	34	16.75%	0	0.00%	130	64.04%	100.00%
MEX	4474	3.98%	20040	17.73%	19041	16.84%	86492	61.47%	100.00%
NIC	107	10.69%	107	10.69%	102	10.19%	688	68.43%	100.00%
PAN	118	5.36%	131	8.06%	250	11.58%	1668	77.02%	100.00%
SLV	44	2.42%	553	30.37%	147	8.07%	1077	59.14%	100.00%
URY	20	1.00%	267	14.40%	568	30.82%	989	53.61%	100.00%
VEN	682	3.02%	5170	23.59%	3698	16.87%	12388	56.52%	100.00%
AVERAGE:		5.97%		16.49%		13.64%		63.90%	
DEVIAT.:		5.48%		7.04%		7.82%		8.84%	
MIN:		1.00%		8.06%		0.00%		53.61%	
MAX:		19.21%		30.37%		30.82%		77.02%	

OECD COUNTRIES

	NAT. SC. LEV 6+7	NAT. SC. LEV 6+7	ENG. LEV 6+7	ENG. LEV 6+7	MED. SC. LEV 6+7	MED. SC. LEV 6+7	OTHER LEV 6+7	OTHER LEV 6+7	TOTAL
COUNTRY	1985	%	1985	%	1985	%	1985	%	%
AUS	8734	17.94%	5108	10.49%	3212	8.80%	31825	64.97%	100.00%
AUT	822	8.49%	1008	10.41%	1869	17.23%	8188	63.87%	100.00%
BEL	2308	9.73%	4481	18.90%	3163	13.34%	13761	58.04%	100.00%
CAN	14812	10.88%	11074	7.98%	9837	7.09%	102988	74.28%	100.00%
CHE	1342	14.88%	881	9.84%	2010	21.99%	4908	53.69%	100.00%
DNK	537	3.30%	1702	16.87%	1710	18.75%	6480	68.28%	100.00%
ESP	7901	14.27%	8731	8.80%	15234	15.36%	87298	67.86%	100.00%
FIN	1378	17.73%	23158	12.83%	9807	12.08%	5648	60.68%	100.00%
FRG	2698	16.78%	1813	11.30%	1794	5.27%	115882	64.17%	100.00%
GRC	15181	3.77%	84973	21.13%	23072	5.74%	278991	69.38%	100.00%
JPN	1814	17.99%	868	9.54%	642	7.18%	5869	66.31%	100.00%
NZL	2280	4.83%	8748	18.79%	5207	11.19%	30348	68.19%	100.00%
USA	144820	10.84%	135581	9.72%	113381	8.28%	981978	71.48%	100.00%
AVERAGE:		11.34%		12.80%		11.37%		64.49%	
DEVIAT.:		5.11%		4.14%		4.88%		5.14%	
MIN:		3.30%		7.98%		5.27%		53.69%	
MAX:		17.99%		21.13%		21.99%		74.28%	

Source: Unesco Computer Tapes

III. SCIENCE EDUCATION IN SECONDARY SCHOOLS

Increased enrollments in scientific and technological fields at the university level requires a growing pool of graduates from Upper Secondary Schools (USS) with an adequate knowledge of science and mathematics. Similarly, the change in attitudes to favor the introduction of technology requires that a large segment of the population be exposed to basic scientific concepts, and be able to relate these concepts to the surrounding physical, social, and economic environment. Proxies for the fulfillment of both requirements are: enrollment rates for lower and upper secondary schools; time dedicated to science and mathematics in the curriculum; and quantity and quality of inputs - teachers, laboratories and equipment, materials, books, teaching methods -.

Enrollment Rates

The Secondary School enrollment rate in SSA is very low. Less than 20% of the secondary school age group attend school compared with almost 90% in Europe and 54% in Latin America. Within this total enrollment rate, that of Lower Secondary School (LSS) is less than 25% while that of the USS is only 10% (see Table III-1). Of this 10% less than 40% follow the "scientific stream" in countries where there is a choice between "humanities" and "science and mathematics" (see Table III-2). Moreover, of those taking the "scientific stream" on the average only 58% pass the science and mathematics exam in their last year (see Table III-2), and of those admitted in the university less than 44% choose a career in Science

and Technology fields. It means that of every ten students admitted in USS only one will end up choosing a career in scientific and technology fields (assuming no dropout along the way).

A low enrollment rate in USS means that in SSA the chances of spotting natural scientific talent 6/ in the general population is 7 to 8 times lower than in Europe, and less than half than that in Latin America. A low enrollment in LSS means that in SSA the proportion of the secondary school population exposed to a systematic program to foster positive attitudes towards technology is four times smaller than in Europe, and that over the long run more than three quarters of the population will remain untouched by modern knowledge and ideas. But even for those lucky enough to enroll in post primary education the quantity and quality of science education leaves much to be desired. On average students in LSS receive 8.6 hours/week of science and mathematics compared with 10.2 hours/week and 10.7 hours/week for Europe and Latin America respectively (see Table III-3). 7/ In USS the number of hours of science and mathematics/week for the "science" streams is 13.4 and for the non science streams 8.5. 8/

Teachers 8/ - Most of the qualified science teachers teach in the USS. The unqualified teachers teach mostly in LSS. In general, a science

6/ D. De Solla Price, op. cit.

7/ The length of LSS varies from country to country. Francophone countries require 4 years, most anglophone 3 years. Length of the school year also varies, but in general the school year in Europe is longer.

8/ Data were calculated from a non-statistical survey of 60 schools distributed among 10 countries.

teacher must possess a secondary school diploma plus 3 or 4 years specialized training at the University or a Teacher Training College (see Table III-4). The percentage of females among these teachers is less than 25%, and this has a negative effect on enrollment of females in the science streams.

Laboratories, equipment, and books in USS. 8/ - In general, they are deficient. Consumables are in short supply. Very few have qualified technicians to take care of the equipment. Science books are available but in short supply. Most students have no access to scientific magazines.

Science Teaching Methods in USS. 8/ - Reading and copying from textbooks are the main teaching vehicles. Lecturing is the principal teaching mode, on average it takes up more than 50% of the time of the teacher. Where laboratories exist, practical work takes up on the average less than 20% of total time allocated to science. There is little technical support from central authorities. The ratio of science inspectors to teachers is less than 1/300.

In Summary:

The secondary school is an integral component of the scientific structure. It supplies the candidates to be trained in science and technology in Higher Education institutions, and is the vehicle for shaping positive attitudes towards modernization. On both accounts the Secondary School System in SSA is falling short of the required task. On average less than 40% of the school population in USS are in the science stream, and of those, given the high rate of failure, almost 50%, only 44% of the

successful ones will go into science, engineering and medicine. It can be easily seen that to increase appreciably the pool of applicants to science and technology at the university level will take a concentrated effort to increase enrollment levels and the proportion of those taking science streams, and also to lower the percent of examination failures in the sciences and mathematics. Concomitantly, enrollment in LSS will have not only to expand to accommodate the expansion of USS, but more importantly, to help expose a larger population to science and technology. To succeed, this quantitative expansion, at both the LSS and the USS, must be accompanied by an improvement of quality through the provision of better teachers, equipment, materials, and educational infrastructure.

- 53 -
ENROLLMENT RATES
TOTAL LOWER AND UPPER GENERAL SECONDARY SCHOOLS IN SSA

TABLE III-1

COUNTRY	LOWER ENR. RATE	UPPER ENR. RATE	TOTAL ENR. RATE
BENIN	20.67%	6.37%	14.98%
BOTSWANA	41.17%	10.18%	29.48%
BURKINA FASO	7.48%	2.65%	6.66%
BURUNDI	3.38%	0.98%	2.37%
CAMEROON	26.75%	10.48%	20.15%
CENTRAL AFRICAN REP	12.00%	5.36%	9.34%
CHAD	6.91%	3.18%	5.39%
COTE D'IVOIRE	22.74%	6.88%	16.34%
ETHIOPIA	21.18%	9.61%	13.73%
GABON	31.95%	9.82%	22.73%
GHANA	60.23%	3.79%	37.74%
GUINEA	10.23%	6.08%	8.54%
GUINEA-BISSAU	7.79%	1.70%	6.45%
KENYA	-	-	21.55%
MADAGASCAR	25.89%	11.83%	20.15%
MALAWI	4.11%	3.94%	4.02%
MALI	8.88%	1.77%	6.34%
MAURITANIA	16.15%	12.84%	14.57%
MAURITIUS	62.18%	52.11%	57.31%
MOZAMBIQUE	10.71%	2.82%	6.11%
NIGER	8.20%	1.64%	5.54%
RWANDA	-	-	1.33%
SENEGAL	16.83%	8.25%	13.37%
SOMALIA	-	-	8.45%
SUDAN	23.61%	11.75%	17.99%
SWAZILAND	54.91%	23.53%	43.35%
TOGO	31.91%	7.13%	21.98%
UGANDA	12.93%	2.18%	9.62%
TANZANIA	4.54%	0.68%	3.39%
ZAMBIA	27.74%	11.12%	18.14%
ZIMBABWE	-	-	63.94%
AVERAGE FOR SSA	22.33%	8.79%	17.60%
EUROPE('87)			89.40%
LATIN AMERICA('87)			53.70%

1] Since enrollment data of lower and upper secondary school in SSA pertain only to general education, and general education is, on the average, around 90% of the total enrollment, enrollment rates for Lower, Upper and Total Secondary education would be 24.6%, 9.7%, and 19.4% respectively.

Source: Calculated from Unesco Statistical Yearbook, 1989

TABLE III-2

STUDENTS IN SCIENTIFIC STREAM IN UPPER SECONDARY SCHOOLS IN SELECTED SSA COUNTRIES

	BURKINA FASO	ETHIOPIA	IV COAST	KENYA	MADAGASCAR	MALAWI	SENEGAL	UGANDA	ZAMBIA
Proportion of Students in Science Streams:	(N.A.)	(N.A.)	(N.A.)	21.99%	60.61%	(N.A.)	50.87%	(N.A.)	30.25%
Passing Rate in Science & Math of Students in these Streams:	55.25%	50.00%	(N.A.)	56.15%	24.72%	68.80%	65.75%	71.63%	75.22%
Percentage of Science Students in Last Year of Upper Secondary School Admitted to University:	33.10%	(N.A.)	35.00%	13.63%	19.38%	(N.A.)	52.80%	(N.A.)	(N.A.)
Percentage of those Admitted going into Science and Technology:	35.00%	(N.A.)	(N.A.)	(N.A.)	48.90%	(N.A.)	48.10%	(N.A.)	(N.A.)

Source: Special Questionnaire

TABLE III-3
Page 1 of 2

WEEKLY CLASS HOURS AND SHARE OF SCIENCE AND MATHEMATICS IN THE TOTAL,
IN LOWER AND UPPER SECONDARY SCHOOLS IN SELECTED SSA COUNTRIES

(GRADES 7-9)				
COUNTRIES	TOTAL TIME (Hours)	SCIENCE	MATHEMATICS	PERCENTAGE SCIENCE AND MATHEMATICS
BOTSWANA	26.9	3.3	4.0	27.1
BURKINA FASO	28.0	3.0	5.0	28.6
CAMEROON	30.0	9.9	5.0	49.7
ETHIOPIA	20.0	2.6	2.6	26.0
GHANA	30.1	3.1	4.0	23.7
KENYA	27.7	3.5	4.7	29.6
MALAWI	28.8	3.3	3.8	24.7
MALI	32.5	5.0	5.0	30.7
MAURITIUS	16.6	3.3	3.3	39.7
NIGER	24.0	3.0	5.0	33.3
RWANDA	32.9	2.7	5.4	24.7
UGANDA	25.3	6.9	4.7	45.8
TANZANIA	30.0	6.0	4.0	33.3
Average for SSA:	27.1	4.3	4.3	32.1
EUROPE:	27.5	6.4	3.8	37.1
LATIN AMERICA:	27.2	6.7	4.0	39.3

Source: The Place of Science and Technology in School Curricula: A Global Survey, Unesco, 1986.

TABLE III-3
Page 2 of 2

UPPER SECONDARY : SCIENCE STREAM

COUNTRIES	TOTAL TIME (Hours)	SCIENCE	MATHEMATICS	PERCENTAGE SCIENCE AND MATHEMATICS
ETHIOPIA	19.6	7.2	3.2	53.06%
KENYA	30.3	6.7	4.0	35.31%
MADAGASCAR	34.0	8.2	5.8	41.18%
SENEGAL	35.0	10.3	6.7	48.57%
ZAMBIA	28.0	8.0	7.0	53.57%
AGERAGE FOR SSA:	29.4	8.1	5.3	46.34%

UPPER SECONDARY : NON-SCIENCE STREAM

COUNTRIES	TOTAL TIME (Hours)	SCIENCE	MATHEMATICS	PERCENTAGE SCIENCE AND MATHEMATICS
ETHIOPIA	19.4	4.4	3.2	39.18%
KENYA	29.6	5.4	4.0	31.76%
MADAGASCAR	35.7	6.0	3.0	25.23%
MALAWI	29.2	6.4	4.4	36.99%
SENEGAL	35.0	2.8	3.0	15.24%
ZAMBIA	28.0	4.0	4.4	30.00%
AGERAGE FOR SSA:	29.5	4.8	3.7	29.73%

Source: Special Questionnaire

TABLE III-4

EDUCATION AND TRAINING REQUIREMENTS OF SCIENCE TEACHERS IN SELECTED SSA COUNTRIES

	ETHIOPIA		KENYA		MALAWI		UGANDA		ZAMBIA	
	LOWER	UPPER	LOWER	UPPER	LOWER	UPPER	LOWER	UPPER	LOWER	UPPER
Secondary School Diploma: +courses:									*	
Teacher Training Certificate:	30.00%									70.00%
10+2:	*									
10+3:			*							
12+1:	*									
12+2:			*		*				*	
(specialization:science)									*	
College Diploma (Educ):	70.00%									20.00%
12+2:	*			*		*	*	*		
12+3:				*	*	*				
12+4:				*		*				*
(specialization:science)				*						
university diploma		100.00%								
B.ED.:						*	*	*		*
w/ 1YR.T.T:			*			*				
(specialization:science)		*	*			*				
B.SC.:			*			*				
3YEARS:				*						
4YEARS:				*						
w/ 1YR.T.T:			*							
w/dipl.ED.:							*	*		
(specialization:science)		*	*	*		*				

* (Alternative Education and Training Attainments Required for Science Teaching)

Source: Special Questionnaire

IV. A STRATEGY FOR SCIENCE EDUCATION IN SSA

Economic development in SSA countries depends foremost on the ability of their societies to establish technological progress as an ongoing process. This ability requires the capacity to choose, acquire, adapt, generate, and apply technologies. ^{9/} Scientific knowledge is a basic ingredient that helps develop this capacity.

The type of scientific knowledge which a country requires at a given time is a function of the technological goals of the society. For example, the level of scientific knowledge required to choose among technologies is different from the one needed to adapt technologies or to generate a new technology. But even the lowest level of technological aspirations demands a local institutional scientific foundation. In SSA this scientific base is needed mainly as an important input to the educational and training processes required to produce the specialized manpower demanded by the economy, and to influence the population at large to accept and encourage technological change. But to function efficiently in these two endeavors the scientific establishment needs to keep up with scientific progress, keep in contact with the scientific international community, and provide its members with opportunities for scientific advancement. For most of SSAn countries, these demands on the scientific

^{9/} Technologies are processes by which knowledge -- cognitive, psychomotor, intuitive, etc. -- is used in the practical solution of problems.

community are a tall order indeed. Not only are budgetary resources constrained but, more importantly, qualified technical scientific personnel are in scarce supply.

Higher education - mostly universities and technical institutes - has been in the past, and will continue to be in the future, a major if not the only source of scientific manpower. How can this institution adjust to fulfill the function of providing the necessary scientific skills, in quantity and quality, that a continuous technological progress demands?

Presently, the numbers of students in, and graduates from, scientific and technological departments in SSAn universities do not correspond to the needs of the countries. Moreover, the gap in scientific and technical manpower per unit of population between SSA and developed countries, and even other developing areas, is widening. This is especially true for graduates with advanced degrees (that require more than 3 or 4 years of post-secondary education) that form the core of those that choose and adapt technologies and teach and train future professionals in scientific and technical areas. The reason for this growing gap is the small number of students that choose science and engineering as their careers, the small graduation rate, and the even smaller number of those that continue to higher levels of training in these fields. How can we reverse this trend?

It is possible to do so by: (1) increasing the total Higher Education student population (leaving the share of science and technology constant), (2) increasing the share of science and technology in the student population, or (3) both.

Given the budgetary constraints of Higher Education in the near future, option (1) of increasing the total number of students to such an extent as to increase significantly the number of graduates in the sciences and technology - a path taken in the past by most SSA countries - is foreclosed. The only available option is option (2) - increasing the share of science and technology. But a shift in the relative shares in favor of science and technology implies an increase in the total budget even if the total number of students remains constant because, in general, cost per student in science and technology are higher than in other areas. To this increase of budget we must also add the cost of improving quality of instruction in science and technology. But the increase in budget to improve quality of instruction has also a positive savings effect. While it increases cost per student, it also increases the probability of promotion and lowers repetition rates. Thus, by increasing the number of graduates from the same pool of admissions it may lower the cost per graduate, where the graduate is, presumably, of a higher quality. The enhancement of quality has also the additional effect of encouraging graduates from one level to seek further training at the next higher level. It is actually at these higher level where the need for graduates in SSA is greatest.

However, even considering the positive impact of quality enhancement on lowering cost per graduate, we must assume that pressures on the budgets for Higher Education will increase. Given the limitations on the budget how can this demand be satisfied? If we want to maintain the enrollment levels in Higher Education, there is no other alternative than

to restructure the budget to favor instruction, and within instruction science and technology, over line items of expenditure that are not directly linked to the educational process. Student maintenance, bourses, and scholarships are obvious candidates for the budgetary ax since their shrinkage will barely affect educational outputs, though it may produce political fallout.

Rearrangement of budgets and the creation of places in science and technology provide opportunities for students to go into these area of specialization, but will the students avail themselves to these opportunities? Present conditions militate against a strong shift in students' preferences toward careers in science and technology. First, science, mathematics, and technology subjects are considered to be harder to cope with than other university curricula. Second, economic rewards, i.e., level of salaries of graduates, do not favor science and technology over other disciplines. The reason why heretofore graduates from science and technology are not doing better than other graduates is that employment opportunities for all types of university graduates were, and continue to be, mostly confined to the public sector where salary scales conform to levels and not types of education. Even in the private sector salary differentials are not large because the low quality of science and technology education blurs differences in the knowledge graduates from different disciplines possess. Furthermore, the productivity of a specific kind of knowledge depends not only on the supply of this knowledge but also on its demand. This has created a chick and egg situation: there is no sufficient demand for scientists and engineers because the rate of technological change is low, but this rate is low because there are not

enough scientists and engineers. A way to break this vicious circle is to provide a supply that is larger, and of a better quality than the one that could be fully employed in the short run, even at the risk of under employment in the short term. Because markets are sometimes slow to react to factors such as quality, whose impact on profitability is not immediately evident, entrepreneurs may have to be educated to the long run gains of employing well qualified science and technology professionals at a reasonable remuneration. While salary differentials are one way of channeling students into careers another way is to reduce or increase the costs of different careers to the individual. Subsidies in the form of scholarships can be provided for students in "desired" programs while discouraging measures, such as tuition fees, can be introduced for students in "unwanted" programs.

Economic incentives are ways to channel applicants into socially desired programs of science and technology, but this presupposes an adequate pool of graduates from secondary schools with a suitable background in science and mathematics. In SSA this pool is rather small. On the average less than 40% of graduates of secondary schools choose a science and mathematics stream, and the rate of success of these streams is less than 60%, and of those admitted to Higher Education less than 45% go into science and technology fields. Sometimes these percentages are determined by administrative fiat, not always decided on the basis of national socio-economic goals, but more often, when the choice resides with the student, enrollments by course are the result of a combination of factors: poor quality of teachers, curriculum, and textbooks and materials;

greater demand on the student's time and efforts by science and mathematics courses; lack of a "visible" reward for the required extra efforts.

To overcome the effect of these factors it will be necessary foremost to improve the quality of science and mathematics for a large number of secondary school students. Given the budgetary constraints and increasing demand for secondary school education, it is not possible to offer quality science and mathematics to all students. The only solution is, first, to target the quality teaching of these subjects to the population that is going to make the best use of this instruction, while providing a good quality but of a different curricula of science and mathematics for the majority of students which in any case are not going into the science and technology fields, and second, to enhance the status of those engaged in science and mathematics by increasing the awareness of the student body, teachers, and parents of the crucial roles that science and mathematics plays in the economic development of the country. This increased status is necessary to reward, albeit partially, students in science streams for the increased time and effort required by science and math curricula.

The possible role of the Bank in the area of science teaching in SSA

In the last 20 years the role of the Bank in science education at the Secondary and Higher Education levels in SSA was quite limited. Of the almost 170 education projects only 12 make specific reference to the need of improving science education, although many more projects for secondary and technical schools include science laboratories as components. It is interesting to note that most of these 12 projects date from the late

1960s to the middle 1970s; the interest in science teaching diminished noticeably since then. (A similar pattern was followed by other international agencies such as AID). It is now high time for the Bank to address the problem of science teaching but not only as one part of a general curricula. Rather, science education should be considered per se an important vehicle for the development of science and technology - the basic ingredients of economic growth. To achieve this there is a need to reassess the old strategies and formulate new ones:

1 - Science and math education should be reviewed as a major input to help the individual fulfill his role in society, especially his function in the economy. To this effect it is important to define what type of science and math is required for the proficient performance in the economy, and what type of science and math is required to function socially. These distinctions in the type of science and math required have methodological (pedagogical) as well as financial implications. Where hitherto the Bank strategy "to improve the quality of science teaching," led to the construction of the same type of science laboratories for everybody, for the future, it is important to target first the audience according to the distinctions made above, and only then decide what inputs should be required in terms of type of curricula, teachers, and materials.

2 - For those occupations that require a more rigorous and advanced science teaching, it is important to provide a quality education commensurate with international standards. This is very costly because of the need for high quality complementary inputs: teachers, materials, curricula, laboratories. With limited physical and financial resources in mosts SSA countries efforts can only be confined to a few "elite" schools.

The trend in the past for the Bank was to foster "equality" which in practice meant spreading the same resources over a larger number of schools. In the case of science and math teaching, to create the right environment and have a minimum quantum of quality resources it will be necessary to concentrate resources in a few "points of excellence." Criteria for equality could be shifted to geography and socio-economic class rather than focusing on schools and students.

3 - For those for whom science and math is required to function as individuals in society, a different curriculum should be developed, perhaps combining knowledge of environmental and health concerns and scientific methodology. To be effective this type of science and math teaching should also be made more culture bound. Certainly, the type of laboratories and materials required for this group would be different from the previous one.

4 - Regarding Higher Education the Bank will have to shift its focus from the financial aspects of Higher Education to the primary function of institutions of higher learning: education, training, quality, and relevance. For too long the emphasis of Bank's policies concerned only cutting costs, shifting financial burdens from government to the public, users fees, etc., while all along little attention was given to the basic problems of low quality teaching and, hence, low quality of graduates. Indeed, present strategy has not lead to increased efficiency of Higher Education.

This shift in strategy is especially important for science and technology sectors of Higher Education. A major focus for the Bank should

be to ensure that the quality of graduates meets international standards. This means that within the Higher Education Science and Technology will have to have a privileged position.

5 - To accelerate science and technology development in higher education, quantitatively and qualitatively, will require extra resources. These can be obtained by shifting resources from non-educational endeavors such as student maintenance and scholarships. It is sometimes argued that these resources be shifted to basic education. While this may be warranted in some cases, the choice is not obvious in many others where the contribution of science and technology to economic development may outweigh that of an increase in literacy rates.

6 - Finally, whatever strategy to foster science and technology education is adopted, it is fundamental that the problem be approached in a comprehensive way. Improvement of secondary school science cannot be done independently of the state of science in the universities, while improvements in science teaching in the university cannot ignore what's going on in secondary schools, the source from which the university draws its students.

Distributors of World Bank Publications

ARGENTINA
Carlos Hirsch, SRL
Calera Guemes
Florida 165, 4th Floor-Ofc 453/465
1333 Buenos Aires

**AUSTRALIA, PAPUA NEW GUINEA,
FIJI, SOLOMON ISLANDS,
VANUATU, AND WESTERN SAMOA**
D.A. Books & Journals
148 Whitehorse Road
Mischam 3132
Victoria

AUSTRIA
Gerold and Co
Graben 31
A-1011 Wien

BALTIKIN
Rebrin Research and Consultancy
Associates Ltd.
P.O. Box 22103
Mamasa Town 317

BANGLADESH
Micro Industries Development
Assistance Society (MIDAS)
House 5, Road 16
Dharmaditya R/Area
Dhaka 1209

Branch office:
156, Nur Ahmed Sarak
Chittagong 4000

76, K.D.A. Avenue
Kulna

BELGIUM
Publications des Nations Unies
Av. du Roi 202
1040 Brussels

BRAZIL
Publicacoes Tecnicas Internacionais
Lda
Rua Pernambuco 209
01409 Sao Paulo, SP

CANADA
Le Diffuseur
C.P. 85, 1301 B rue Ampere
Boucherville, Quebec
J4B 5B6

CHINA
China Financial & Economic Publishing
House
8, Da Fo Si Dong Jie
Beijing

COLOMBIA
Enteasa Ltda.
Apartado Aereo 34270
Bogota D.E.

COTE D'IVOIRE
Centre d'Édition et de Diffusion
Africaines (CEDA)
08 B.P. 541
Abidjan 04 Plateau

CYPRUS
MEMRB Information Services
P.O. Box 2398
Nicosia

DENMARK
Samfundslitteratur
Rosengade A/S 11
DK-1970 Frederiksberg C

DOMINICAN REPUBLIC
Editores Talleres, C. por A.
Restauracion e Isabel la Catolica 309
Apartado Postal 2190
Santo Domingo

EL SALVADOR
Fuentes
Avenida Manuel Enrique Arce 4350
Edificio SISA, 1er. Piso
San Salvador

EGYPT, ARAB REPUBLIC OF
Al-Ahram
Al-Galaa Street
Cairo

The Middle East Observer
8 Chawarbi Street
Cairo

FINLAND
Akademien Kirjakauppa
P.O. Box 128
SF-00101
Helsinki 10

FRANCE
World Bank Publications
66, avenue d'Alsace
75114 Paris

GERMANY, FEDERAL REPUBLIC OF
UNO-Verlag
Poppendorfer Allee 55
D-5000 Bonn 1

GREECE
KEME
96, Ippokratous Street Platis Platanos
Athens-11635

GUATEMALA
Librerias Piedra Santa
Centro Cultural Piedra Santa
11 calle 6-50 zona 1
Guatemala City

HONG KONG, MACAO
Asia 2000 Ltd.
Mongkok Post Office
Bute Street No. 37
Mongkok, Kowloon
Hong Kong

HUNGARY
Kultur
P.O. Box 139
1389 Budapest 62

INDIA
Albion Publishers Private Ltd.
751 Mount Road
Madras - 600 002

Branch office:
15 J.N. Heredia Marg
Ballant Estate
Bombay - 400 008

13/14 Asaf Ali Road
New Delhi - 110 002

17 Chittaranjan Avenue
Calcutta - 700 072

Jayadeva Hostel Building
5th Main Road Gandhinagar
Bangalore - 560 009

3-5-1129 Kachiguda Cross Road
Hyderabad - 500 027

Prarthana Plaza, 2nd Floor
Near Thakare Bungalows, Navrangpura
Ahmedabad - 380 009

Patela House
16-A Ashok Marg
Lucknow - 226 001

INDONESIA
Pt. Indira Limited
Jl. Sam Ratulangi 37
P.O. Box 181
Jakarta Pusat

IRELAND
TTIC Publishers
12 North Frederick Street
Dublin 1

ITALY
L'Espresso Comunitaria Sanatori SPA
Via Benedetto Forlani, 130/10
Casella Postale 552
10125 Florence

JAPAN
Eastern Book Service
37-3, Hongo 3-Chome, Bunkyo-ku 113
Tokyo

KENYA
Africa Book Service (E.A.) Ltd.
P.O. Box 45245
Nairobi

KOREA, REPUBLIC OF
Pan Korea Book Corporation
P.O. Box 101, Kwangwhamun
Seoul

KUWAIT
MEMRB Information Services
P.O. Box 5665

MALAYSIA
University of Malaya Cooperative
Bookshop, Limited
P.O. Box 1127, Jalan Pantai Baru
Kuala Lumpur

MEXICO
INPOTEC
Apartado Postal 22-860
14060 Tlalpan, Mexico D.F.

MOROCCO
Societe d'Etudes Marketing Marocaine
17 rue Mozart, Bd. d'Anfa
Casablanca

NETHERLANDS
InCo-Publicaties b.v.
P.O. Box 14
7240 BA Lelidam

NEW ZEALAND
Hills Library and Information Service
Private Bag
New Market
Auckland

NIGERIA
University Press Limited
Three Crowns Building Jericho
Private Mail Bag 5095
Ibadan

NORWAY
Narvesen Information Center
Bertrand Narvesens vei 2
P.O. Box 6125 Rittenstad
N-2200 Oslo 6

OMAN
MEMRB Information Services
P.O. Box 1613, Soob Airport
Muscat

PAKISTAN
Mirza Book Agency
65, Sh. Ibrahim-e-Qasid-e-Azam
P.O. Box No. 729
Lahore, 3

PERU
Editorial Desarrollo SA
Apartado 3824
Lima

PHILIPPINES
National Book Store
701 Rizal Avenue
P.O. Box 1954
Metro Manila

POLAND
ORFAN
Pasek Kultury i Nauki
03-603 Warszawa

PORTUGAL
Livraria Portugal
Rua Do Carmo 75-74
1300 Lisboa

SAUDI ARABIA, QATAR
Jari Book Store
P.O. Box 3196
Riyadh 11471

MEMRB Information Services
Branch office:
Al Alaa Street
Al Dahna Center
First Floor
P.O. Box 7188
Riyadh

Haji Abdullah Alaresa Building
King Khalid Street
P.O. Box 3969
Dammam

33, Mohammed Hassan Awad Street
P.O. Box 3978
Jeddah

**SINGAPORE, TAIWAN, MYANMAR,
SRI LANKA**
Information Publications
Private, Ltd.
02-06 1st Fl., Pui-Pu Industrial
Bldg
24 New Industrial Road
Singapore 1953

SOUTH AFRICA, BOTSWANA
For single titles:
Oxford University Press Southern
Africa
P.O. Box 1141
Cape Town 8000

For subscription orders:
International Subscription Service
P.O. Box 41095
Craighall
Johannesburg 2024

SPAIN
Mundo-Prensa Libros, S.A.
Castello 37
28001 Madrid

Literaria Internacional AEDOS
Concell de Cant, 391
08009 Barcelona

SRI LANKA AND THE MALDIVES
Lake House Bookshop
P.O. Box 284
100, Sir Chittampalam A. Gardiner
Mawatha
Colombo 2

SWEDEN
For single titles:
Prisma Fackboksförväg
Bogtryckeriet 12, Box 16356
S-103 27 Stockholm

For subscription orders:
Winnberg-Williams AB
Box 30004
S-104 25 Stockholm

SWITZERLAND
For single titles:
Librairie Payot
6, rue Grenus
Case postale 381
CH-1211 Geneva 11

For subscription orders:
Librairie Payot
Service des Abonnements
Case postale 3312
CH-1002 Lausanne

TANZANIA
Oxford University Press
P.O. Box 9299
Dar es Salaam

THAILAND
Central Department Store
306 Silom Road
Bangkok

**TRINIDAD & TOBAGO, ANTIGUA,
BARBUDA, BARBADOS,
DOMINICA, GRENADA, GUYANA,
JAMAICA, MONTserrat, ST.
KITTS & NEVIS, ST. LUCIA,
ST. VINCENT & GRENADINES**
Systematics Studies Unit
#9 Watta Street
Curepe
Trinidad, West Indies

TURKEY
Halet Kizilirmak, A.S.
Ismikl Caddesi No. 469
Beyoglu
Istanbul

UGANDA
Uganda Bookshop
P.O. Box 7145
Kampala

UNITED ARAB EMIRATES
MEMRB Gulf Co.
P.O. Box 6097
Sharjah

UNITED KINGDOM
Microfilm Ltd.
P.O. Box 3
Alton, Hampshire GU34 2PG
England

URUGUAY
Instituto Nacional del Libro
San Jose 1116
Montevideo

VENEZUELA
Libreria del Este
Aptdo. 40 337
Caracas 1060-A

YUGOSLAVIA
Jugoslavenska Knjiga
P.O. Box 36
Trg Republike
YU-11000 Belgrade

RECENT WORLD BANK TECHNICAL PAPERS (continued)

- No. 93 Batstone, Smith, and Wilson, *The Safe Disposal of Hazardous Wastes: The Special Needs and Problems of Developing Countries*
- No. 94 Le Moigne, Barghouti, and Plusquellec, *Technological and Institutional Innovation in Irrigation*
- No. 95 Swanson and Wolde-Semait, *Africa's Public Enterprise Sector and Evidence of Reforms*
- No. 96 Razavi, *The New Era of Petroleum Trading: Spot Oil, Spot-Related Contracts, and Futures Markets*
- No. 97 Asia Technical Department and Europe, Middle East, and North Africa Technical Department, *Improving the Supply of Fertilizers to Developing Countries: A Summary of the World Bank's Experience*
- No. 98 Moreno and Fallen Bailey, *Alternative Transport Fuels from Natural Gas*
- No. 99 International Commission on Irrigation and Drainage, *Planning the Management, Operation, and Maintenance of Irrigation and Drainage Systems: A Guide for the Preparation of Strategies and Manuals (also in French, 99F)*
- No. 100 Veldkamp, *Recommended Practices for Testing Water-Pumping Windmills*
- No. 101 van Meel and Smulders, *Wind Pumping: A Handbook*
- No. 102 Berg and Brems, *A Case for Promoting Breastfeeding in Projects to Limit Fertility*
- No. 103 Banerjee, *Shrubs in Tropical Forest Ecosystems: Examples from India*
- No. 104 Schwabe, *The World Software Industry and Software Engineering: Opportunities and Constraints for Newly Industrialized Economies*
- No. 105 Pasha and McGarry, *Rural Water Supply and Sanitation in Pakistan: Lessons from Experience*
- No. 106 Pinto and Besant-Jones, *Demand and Netback Values for Gas in Electricity*
- No. 107 Electric Power Research Institute and EMENA, *The Current State of Atmospheric Fluidized-Bed Combustion Technology*
- No. 108 Falloux, *Land Information and Remote Sensing for Renewable Resource Management in Sub-Saharan Africa: A Demand-Driven Approach (also in French, 108F)*
- No. 109 Carr, *Technology for Small-Scale Farmers in Sub-Saharan Africa: Experience with Food Crop Production in Five Major Ecological Zones*
- No. 110 Dixon, Talbot, and Le Moigne, *Dams and the Environment: Considerations in World Bank Projects*
- No. 111 Jeffcoate and Pond, *Large Water Meters: Guidelines for Selection, Testing, and Maintenance*
- No. 112 Cook and Grut, *Agroforestry in Sub-Saharan Africa: A Farmer's Perspective*
- No. 113 Vergara and Babelon, *The Petrochemical Industry in Developing Asia: A Review of the Current Situation and Prospects for Development in the 1990s*
- No. 114 McGuire and Popkins, *Helping Women Improve Nutrition in the Developing World: Beating the Zero Sum Game*
- No. 115 Le Moigne, Plusquellec, and Barghouti, *Dam Safety and the Environment*
- No. 116 Nelson, *Dryland Management: The "Desertification" Problem*
- No. 117 Barghouti, Timmer, and Siegel, *Rural Diversification: Lessons from East Asia*
- No. 118 Pritchard, *Lending by the World Bank for Agricultural Research: A Review of the Years 1981 through 1987*
- No. 119 Asia Energy Technical Department, *Flood Control in Bangladesh: A Plan for Action*
- No. 120 Plusquellec, *The Gezira Irrigation Scheme in Sudan: Objectives, Design, and Performance*
- No. 121 Listorti, *Environmental Health Components for Water Supply, Sanitation, and Urban Projects*
- No. 122 Dessing, *Support for Microenterprises: Lessons for Sub-Saharan Africa*
- No. 123 Barghouti and Le Moigne, *Irrigation in Sub-Saharan Africa: The Development of Public and Private Systems*

The World Bank

Headquarters

1818 H Street, N.W.
Washington, D.C. 20433, U.S.A.

Telephone: (202) 477-1234
Facsimile: (202) 477-6391
Telex: WUI 64145 WORLDBANK

RCA 248423 WORLDBK
Cable Address: INTBAFRAD
WASHINGTONDC

European Office

66, avenue d'Iéna
75116 Paris, France

Telephone: (1) 40.69.30.00
Facsimile: (1) 40.69.30.66
Telex: 640651

Tokyo Office

Kokusai Building
1-1 Marunouchi 3-chome
Chiyoda-ku, Tokyo 100, Japan

Telephone: (3) 3214-5001
Facsimile: (3) 3214-3657
Telex: 26838

